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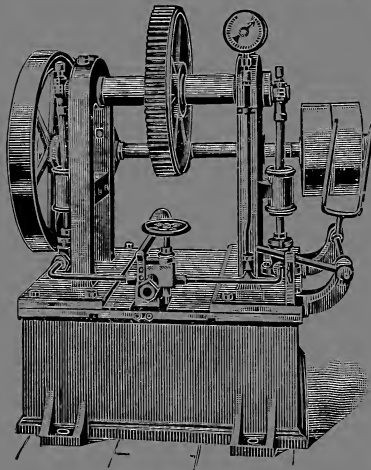
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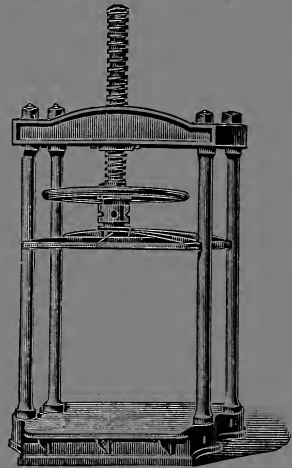
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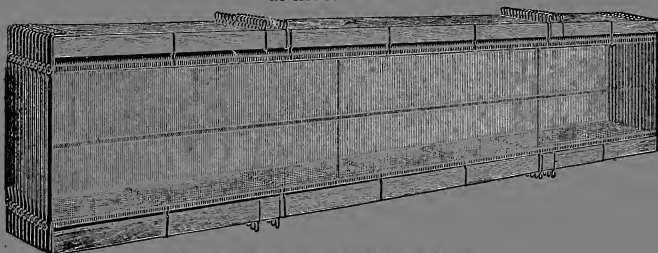
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TEXTILE CALCULATIONS  
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[ENTERED AT STATIONERS' HALL.]



Yours truly  
J. D. [Signature]

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A TREATISE ON

# TEXTILE CALCULATIONS

AND THE

# STRUCTURE OF FABRICS,

BY

THOS. R. ASHENHURST,

*Upwards of fifteen years Head Master, Textile Department,  
Bradford Technical College.*

*Author of a Practical Treatise on Weaving and Designing ;  
An Album of Textile Designs ; Designs in Textile Fabrics,  
&c., &c., &c.*

FIFTH EDITION.

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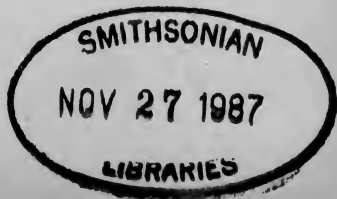
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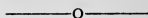
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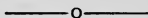
THE demand for still another edition of this work is to me convincing proof of its general utility, and in acknowledging the support thus rendered, an intimation of any discrepancy that may have arisen in its progress through the Press, will be thankfully received by the Publishers.

THOS. R. ASHENHURST.

1902.



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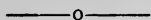


THE call for a fourth edition of this work is most gratifying, and confirms the belief that it is supplying a want. Since the issue of the previous edition I have found nothing to modify my opinions and the rules of Cloth Structure laid down in Appendix A, beyond the correction of errors. I can only trust that the work will fulfil its mission.

THOS. R. ASHENHURST.

*Bradford, October, 1893.*

## PREFACE TO THIRD EDITION.



SINCE the second edition of this book was issued, I have had opportunities for continuing some of the investigations in Cloth Structure which at that time were very incomplete; the results will be found in the Appendix A. There is still room for further research, and if what is contained in this volume, assists and stimulates others, something will have been gained, and the demand for the book, and its success generally, warrants the belief that this may be the case, and at least suggest that a want has been supplied.

• THOS. R. ASHENHURST.

*Bradford, June, 1890.*



## PREFACE TO SECOND EDITION.

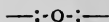


IN preparing a second edition of this book for the press, many of the errors which appeared in the first edition have been corrected, and some slight additions made. It is, however, more than probable that some mistakes have escaped notice, or even that others have crept in; readers who may discover such would confer a great favour by bringing them before the Author.

THOS. R. ASHENHURST.

*Bradford, May, 1886.*

## P R E F A C E .



IN many respects the character of this work differs from any other which has hitherto been issued to the public. The great diversity which exists of the systems of indicating the weights, or as they are termed the counts of yarn, of what are known as the sett systems, and generally of the modes of calculating yarns and fabrics, have made this one of the most difficult subjects with which the manufacturer has had to deal. There can be no doubt but it would be beneficial to the trade generally if some fixed and universal system could be adopted. Looked at from a common sense point of view, there does not seem to be any insuperable difficulties in the way of this being done; yet, there is no doubt that any attempt to introduce one system would meet with strong opposition from many quarters; though, why such opposition should be offered, is not easy to explain. It would, surely, be easier to reckon setts by one common unit of measurement, one inch, than by some of the cumbrous systems in use; for no matter what may have been the reasons for their original introduction and use, there can be no question that at the present time, for all practical purposes, they have to be reduced to the inch basis, and all calculations worked from that, in one form or another. In the same manner, with respect to the counting of yarns, the lb., oz., or dram, is made the unit in one form or another,

then why could it not be made so direct, instead of having a roundabout and elaborate system of arriving at it. Of all the systems in use, but few have anything to recommend them to the practical mind. They are difficult to understand, and equally difficult to apply to practice. Of course it may be said by a man who has been in the habit of working upon one system for years, that it is quite easy for him to deal with it. So it may be; but it is only familiarity, born of long practice in the working of it which has made it easy. Would not a more simple method of counting, having for its basis some weight in common use, be equally easy? And would not a knowledge of its basis be more easily acquired and remembered? And beyond, and more important than this, an universal system of counting yarns, no matter what the basis of the system, must conduce to better working, and freer intercourse between the various branches of the Textile Trade. It is to be hoped that, by some means, this uniformity will be obtained.

In the second section of this work, an attempt has been made to reduce the principle of the structure of fabrics to a definite and systematic basis. Of the truth of the general principles laid down, there can be no manner of doubt. The application of some of these principles in practice, may possibly be open to criticism. They are put forward with a view to assist in bringing the principles of the structure of cloths within definite rules, or, if the term may be used, to "assist in the development of the science of cloth building." There can be no reason why cloths should not be

built upon scientific principles as well as any other structure. The conditions under which they are to be used are as well known as the conditions of use of any other structure or fabric. The materials from which they are made are well known; then what should there be to prevent the application of fixed laws and rules to the building of fabrics, as well as to the building of roads and bridges, &c.?

Thanks are due to the manufacturers and spinners who have supplied yarn for the purpose of the trials and measurements which have been made, and which have tended very materially to make the second section of the work as complete as it is.

The object of this treatise has been to formulate some of these rules, and to endeavour to lay down some system. It may not be complete; it scarcely can be; but if it should be the first seed: if it should do anything to assist in the development of this science of cloth building, then it will not have failed in the object with which it has been written; and that it may assist those engaged in the manufacture of Textile Fabrics, and in the further development of fixed and true principles, is the fervent wish of its Author,

THOS. R. ASHENHURST.

*Bradford, July, 1884.*



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A TREATISE ON  
TEXTILE CALCULATIONS  
AND THE  
STRUCTURE OF FABRICS.



INTRODUCTION.

WHAT are the calculations required in the Textile manufactures? and what purposes do they serve? are questions which may well be asked before entering into the subject, or beginning to deal with the calculations from a practical standpoint. One of the chief purposes which those calculations serve, and one to which attention is generally first directed, is to ascertain the quantity of material required for the formation of a piece of fabric, and the cost of its production. Beyond this there are other considerations which are of quite as much importance, though receiving considerably less attention from the manufacturers and designers of fabrics. Foremost of these is the question of the quantity of material required to make a perfect fabric of a given character or pattern.

It may be at once conceded that those are the two chief purposes, and others of a less important yet necessary character are contributory to one or other of these two. Before however commencing to make the calculations required for either of the two chief purposes named, it is necessary to have some standard gauge or measurement for the yarns or material from which the fabrics are made, as well as for the distances apart of the various threads composing it. Further, these standard measurements are necessary to enable us to communicate to others the particulars of the sizes of the yarns, the number of threads in a given space, and other details for the construction of a piece of fabric, or for preserving a record of how a particular cloth has been made, so that it may be reproduced at any time, as well as for ascertaining its weight, cost, &c.

If it were necessary, rough comparisons of this system of weights and measures—if the term is permissible—to other systems might be made, for the purpose of impressing upon the reader the necessity for some intelligible basis. It is well known that the apothecary must have a system of weights and measures to enable him to prepare the compounds which he dispenses. The surveyor must have his system of measures to enable him to express to others the areas, &c., of land, and in like manner, we must all have some mode of

expressing our ideas of quantities—actual or relative—and in many instances the expression of these quantities or the mode of measuring them, may be peculiar to the particular material or substance being dealt with.

In Yarns—the material from which woven fabrics are made—it is obvious that the simplest and easiest mode of computing must be by some method of indicating that a certain length weighs a given weight, or what is equivalent to that, that there should be some unit of length, and fixed standard weight, and that the number of those units which go to make up this weight, shall be the indication of the thickness or bulk of the thread. In like manner, some method of expressing the number of threads in a given space must be adopted, so that the total number in the whole fabric may be ascertained. Having adopted these means of expressing weight or dimensions of yarns, it will become an easy matter to determine the weight or texture of a piece of cloth. Having reached this point, it seems as if there should be little or no difficulty in fixing a standard unit of measurement or weight upon which the calculations may be based. Whether the inch or the yard be taken as our unit of length, and take the pound, ounce, or dram, of the apothecaries, the avoirdupois, or any other system of weights, as our unit of weights, certainly there should be

no difficulty. Yet the fact remains that there are innumerable systems in use in the different manufacturing districts, each having a different basis ; and this difference exists not only as to the counts or method of indicating the weight of yarn, but also as to the mode of determining the number of threads in a given space.

Many of these systems or basis of calculations are the result of local custom, and at the time of their first establishment, no doubt had something to recommend them in most cases ; whether those reasons exist now is a different matter ; but recognizing the fact of their existence, it will be necessary to deal with some of them in detail before entering into the question of their application, either in determining the weight and cost, or the structure of fabrics, so that the rules laid down will be more readily understood, and more easily applied.





## THE COUNTS OF YARNS.

IN indicating the counts of yarn, or the number of given units of measurement which go to make up a given weight, it would seem as though the decimal system would be the simplest, and the one upon which calculations might be most easily worked; and it is very probable that if an entirely new system had now to be established, it would be upon this basis. There are certainly one or two systems in use to which attention will have to be called, which do somewhat approximate to this, and which are consequently very easy of application, but the majority of the systems in use are of such a complex character, that one must be thoroughly conversant with them from long practice before they can be readily applied; and even then, if several different materials have to be dealt with, each one being required to be calculated on a different basis, it becomes a difficult matter, sometimes, to avoid mistakes. Most of the systems in use are based upon the number of "hanks," "cuts," or "skeins," which go to weigh one pound avoirdupois, but some few are based upon the yards per ounce, &c. All these it will be necessary to examine as carefully as possible, so as to arrive at a clear understanding of their basis, and to enable us to apply them readily in practice.

It will be as well, perhaps, to begin with those systems based upon the hank first, as they will form a sort of key to many of the others, and enable the student to understand them more readily.

WORSTED YARNS are calculated by the hank of 560 yards, and the number of hanks which weigh

one pound avoirdupois indicate the counts, thus if 20 of such hanks weigh one pound, the yarn is said to be 20's, or if 60 hanks weigh one pound, it is said to be 60's. The hank is made up as follows:—By the old system of reeling—only practised now for a few special classes of yarn—all worsted yarns were reeled or made up into hanks upon a reel of one yard circumference; at the end of the reel was attached an indicator, which was so arranged, that at every 80 revolutions of the reel a small spring gave a “rap” or “snap,” consequently 80 yards was termed one “rap;” at the rap the reel was moved slightly to one side, so that the next “rap” was wound separately, and so on until seven “raps” had been made, then the seven “raps” were made up into one “hank;” consequently the “hank” consists of seven “raps” of 80 yards each, or equal to 560 yards, and this “hank” becomes as already mentioned, the unit of measurement, and upon the basis of the number of those units which go to weigh one pound avoirdupois, all the calculations of worsted yarns are made.

A further intricacy also exists in dealing with worsted yarns, and one which is peculiar to this class, more especially those used for wefts, *viz* :—that they are sold by the gross of twelve dozen, or 144 hanks; so that the cost of the weft required to make a piece of fabric is not reckoned by the price per lb., but by the price per gross; and in all calculations for cost of weft, the yarn must be reduced to this denomination, and to determine the weight they must be based upon the hanks per lb.

In COTTON YARNS a similar system of indicating the counts of yarn prevails to that of worsted, but the hank consists of 840 yards instead of 560.

The length of the cotton hank is determined in precisely the same manner as worsted, the difference in the length of the hank being brought about by the difference in the circumference of the reel, which is 54 inches instead of 36, or  $1\frac{1}{2}$  yards instead of 1 yard. The number of hanks per lb. indicates the counts, so that taking the same counts of yarn in cotton and worsted, one will represent one half more yards per lb. than the other.

In those two materials, the systems of indicating the counts of yarn are general throughout the United Kingdom.

SPUN SILKS are calculated on the same basis as cotton. The same number of yards—840—making one hank, and the number of hanks weighing one pound indicating the counts. There is one important difference between spun silk, and the other two materials already mentioned, which requires to be carefully borne in mind when making calculations. This difference refers to two-fold yarns only. When speaking of two-fold worsted or cotton, the actual counts of the yarn is only half of what it is termed; thus in speaking of two-fold 60's cotton or worsted the actual counts of the yarn is 30's, simply because it consists of two threads of 60's twisted together, thus making one thread double the weight of the original single thread, consequently if the yarn in its original or single state required 60 hanks to weigh one pound, the resulting thread (when two are put together) will only require thirty hanks to weigh one pound. In spun silk, whatever counts the yarn is termed, that number of hanks are required to make one pound, whether single or two-fold. Thus in speaking of 60's silk, whether it be single or two-fold yarn, sixty hanks per lb. are indicated. The usual method of writing two-fold counts in

worsted or cotton as two-fold 60's for example is 2/60's, thus indicating that the yarn consists of two threads of 60's put together, but in silk it is written 60/2, conveying at once that the yarn is still 60's, though a two-fold yarn, or consisting of two threads twisted together.

Perhaps to anyone not familiar with the system of indicating counts, this difference in the mode of writing the counts of two-fold yarns might not be quite clear, and consequently mistakes may be easily made; and even to one familiar with the system, when dealing with the two materials at the same time, as is often done, it is easy to make mistakes through the least negligence or forgetfulness.

**RAW SILKS.** While spun silks are calculated on the same basis as cotton—with the exception of two-fold yarns, as pointed out above—raw silks are calculated on a totally different basis, or rather, there are several systems, each having a different basis. What is probably the oldest of these, that known as the "Denier" scale seems to be a somewhat doubtful quantity, or rather there are differences of opinion as to the value of the denier, and the length of the hank. The value of the denier has been variously described as "20 of which are equal to  $16\frac{1}{2}$  grains;" as "32 deniers to a dram;" and Dr. Ure says, he understood the denier to be equal to 0.693 of an English grain, but upon testing a denier weight, he found it to be equal to 0.833 of a grain. I am credibly informed that an acknowledged authority—the London Silk Conditioning House—gives the weight of the denier at  $533\frac{1}{3}$  equal to 1 oz. avoirdupois. On the basis of 20 deniers equal to  $16\frac{1}{2}$  grains, the value of the weight would be 0.825 of a grain. On the basis of 32 deniers to a dram, it would be

0.854 of a grain; and on the basis of the Silk Conditioning House, it would be 0.8203+ of a grain.

Then with respect to the length of the hank, it has been variously expressed as "generally 400 revolutions of a reel made for the purpose;" and as "*about* 400 yards," &c. The Silk Conditioning House giving it as 400 French ells, or equal to 520 yards. This agrees with the basis actually in use in some districts, so that it may be taken as practically correct. Other methods of indicating the counts of silk are by the hank of 1000 yards; in one case the number of such hanks weighing one ounce indicating the counts, thus if 30,000 yards weigh one ounce, it would be called 30's, or 30,000's.

Another method of indicating the counts by the use of the 1000 yards hank, is by taking its weight in drams, thus if one hank weighs 3 drams, it is termed 3 dram silk, or if it weigh  $4\frac{1}{2}$  drams, it would be termed  $4\frac{1}{2}$  dram silk.

Either of these methods is very easy to deal with in making calculations, much easier than the denier scale, and as a consequence are now much more largely used.

LINEN YARN is calculated upon the basis of the "lea" of 300 yards, the general mode of indicating the counts being the number of "leas" weighing 1 lb., and is the only one which has been interfered with or governed by law in this country; this regulation applying only to the length of the "lea," "hank," or "cut."

WOOLLEN YARNS. It is in woollen yarns where perhaps of all others the greatest diversity prevails in the basis or system, and it would scarcely be possible to give all the systems which are in use,

for every district has its own system, and in many cases individual firms have a system of their own the basis of which is known only to a few heads of departments.

Generally speaking (in England at least) woollen yarns are calculated by the skein, but as a unit of calculation the skein varies in different districts, and in many cases the system is very imperfectly understood, and the actual skein has fallen into disuse although some equivalent has been found for it, and which, bearing a proportionate value, simplifies the calculations.

Take what is termed the YORKSHIRE SKEIN, which is used in the Leeds and Huddersfield districts, as an example, it will shew what has been the origin of the skein, and how it has been simplified, and it will also serve as a key to the curious, which will enable them to arrive at the probable origin of some of the other systems. This system is based upon the old method of "slubbing," &c., when in preparing the wool for working, it had to be weighed in small quantities. Each of those weighings was termed a "wartern" or "whartern," and was equal to 6 lbs. avoirdupois, and as each lb. contains 256 drams, each "wartern" contained 1536 drams. Then what is termed a skein, is what in other materials is known as a hank, and contains as many yards as there are drams in one wartern. Therefore the Yorkshire skein contains 1536 yards.

To indicate the counts of the yarn, as many skeins as weigh—or are made from—one "wartern" such is the counts, thus:—if one wartern makes only one skein of yarn, or 1536 yards, the counts of that yarn is 1's, but if it makes 20 of such skeins, the counts is 20's. Then there being the same number of yards in one skein as there are

drams in one wartern, whatever number of skeins of yarn one wartern makes the same number of yards of yarn will weigh one dram.

Upon this principle the weight of the wartern may be anything, and if the same number of yards make one skein, as drams make one wartern, the counts of the yarn will always be indicated by the yards per dram.

This simplifies the calculations very much, because the whole thing may be said to rest upon the number of yards weighing one dram, and although the terms "skein" and "wartern" are still employed they are practically merely terms of convenience, used to express a known quantity. Yards and drams might for all practical purposes be substituted for them.

Sometimes woollen yarn is reckoned by the HANK of 840 yards, in the same manner as cotton, but generally when this is done, the number of hanks does not indicate the counts, but one half is added; thus if there are 20 hanks per lb., the yarn would not be termed 20's, but it would be 30's, or making it exactly equal to worsted counts, as  $\frac{20 \times 840}{560} = 30$ .

The system in use in the WEST OF ENGLAND is based upon 20 yards per ounce, or 320 yards per lb., so that the number of times 20 yards of yarn are contained in one ounce indicates the counts; thus if 400 yards (20 times 20) weigh one ounce, the yarn would be 20's, or if 480 (20 times 24) weigh one ounce, it would be 24's.

Another system which is not much practised now, known as the "CUMBERLAND BUNCH COUNT," determines the counts of yarn by the ounces weight of a bunch of 3.360 yards. This bunch is

equal to four cotton, or six worsted hanks, and originated in the old system of tying up the yarn in bunches of so many hanks each.

What is known as the DEWSBURY system is based upon the number of yards per ounce; thus 24 yards weighing one ounce would be termed 24's yarn, and in like manner for any counts.

IN SOWERBY BRIDGE, in Yorkshire, the counts are based upon the weight in drams of 80 yards, in a similar manner to indicating the counts of silk by the weight in drams of 1000 yards; thus whatever number of drams 80 yards will weigh, the weight indicates the counts. If it should weigh 4 drams, it would be termed 4's, if 6 drams, it would be 6's yarn, and so on.

IN SCOTLAND the diversity in the systems is quite as great, if not even greater, than in England. At Galashiels the counts system is based upon the number of cuts of 300 yards each in 24 ounces, or 384 drams. At Hawick, it is based upon the cuts of 300 yards each in 26 ounces, or 416 drams

In some districts in Scotland, the "SPYNDLE" is made the basis of the counts, but this like other units of calculation, is a variable quantity. That in use at Stirling, and some other places, is based upon 48 cuts, of 240 yards each, or equal to 11,520 yards, and the unit of weight is 24 lbs., the number of "spyndles" contained in that weight indicating the counts, or equal to 480 yards per lb. The Aberdeen "spyndle" contains 48 cuts of 300 yards each, or equal to 14,400 yards, and the number of lbs. which the "spyndle" weighs indicates the counts; thus, if a "spyndle" weighs 1 lb., it would be termed 1's, or 1 lb. yarn, if it weighs 3 lbs., it



would be 3's, or 3lb. yarn. The following is a complete table of this system :—

120 Threads (90 in. each	= 1 Cut	= 300 yds.
2 Cuts	... .. = 1 Heer	= 600 ,,
3 Heers	... .. = 1 Slip	= 1,800 ,,
2 Slips	... .. = 1 Hank	= 3,600 ,,
2 Hanks	... .. = 1 Hesp	= 7,200 ,,
2 Hesps	... .. = 1 Spynkle	= 14,400 ,,

AMERICA has in her woollen manufactories her own systems. Those in general use there, are the "run," the "grain," and the "cut" systems. The "run" is based upon 100 yards per oz., or 1,600 yards per lb., so that 100 yards weighing one ounce would be 1 "run" yarn, and 400 yards weighing one ounce, would be 4 "run" yarn.

The "grain" system is based upon the weight in grains of 20 yards; thus if 20 yards weigh 16 grains, it is 16's, or 16 grain yarn; if it weighs 20 grains, it is 20's or 20 grain yarn.

In the "cut" system, the number given as counts indicates the cuts of 240 yards each weighing 1 lb., the following is a table of this system :—

240 Yards	=	1 Cut
8 Cuts	=	1 Head
6 Heads	=	1 Spynkle

Another system, also known in America, is based upon "holes," the "hole" containing 60 yards.

It might not be out of place here, for the purpose of showing the relative value of the different systems, to make a comparison of the number of yards per lb. of a given count in all the various systems mentioned, as that will convey what is desired at a glance more completely and readily than pages of description. Taking 20's,—a count which is very common in many of the systems - and finding the number of yards per lb.

of that counts in each of the systems, it will show very readily their relative values.

The list is as follows :—

	Yards per lb.
WORSTED ... .. 20'S	= 11,200
COTTON ... .. "	= 16,800
SPUN SILK ... .. "	= 16,800
RAW SILK (1000 yds. per oz.)	= 320,000
" (1000yds. per dram)	= 12,800
" (Denier Scale) ...	= 13,866 $\frac{2}{3}$
LINEN (Ordinary) ... .. "	= 6,000
WOOLLEN (Yorkshire Skein)	= 5,120
" (West of England)	= 6,400
" (Dewsbury) ...	= 320
" (Bunch Count) ...	= 2,688
" (Sowerby Bridge)	= 1,024
ABERDEEN ... .. "	= 720
STIRLING ... .. "	= 9,600
GALASHIELS ... .. "	= 4,000
HAWICK ... .. "	= 3,692 $\frac{4}{13}$
AMERICAN "RUN" ... .. "	= 32,000
" "GRAIN" ... .. "	= 7,000

Taking the above systems, and there are many others not mentioned, it will be seen that yarn known by the same number may vary from 320 to 320,000 yards per lb. This points very clearly to the desirability of having some fixed and recognised standard measurement for the counts of yarn.

A further comparison might be made which will possess some value for reference. Instead of showing the yards per lb. for a given counts, take a fixed counts in one yarn or system, and see what would be the counts for a yarn exactly equal to it in any other yarn or system. A most valuable "Comparative Yarn Table" of this description has been recently published by Messrs. McLennan, Blair & Co., Yarn Merchants, of Glasgow, showing the relative counts in a large number of yarns and

systems. For the present purpose one comparison will be sufficient, and for convenience the same counts as that employed in the comparison just given may be again used, *viz.*:—20's, and take worsted as the standard (cotton is very frequently employed for this purpose), then taking the number of yards contained in 1 lb. of 20's worsted, it will be necessary to find what counts that number of yards per lb. would represent in the various systems. 20's worsted is equal to 11,200 yards per lb., that number of yards per lb. would give us in

COTTON	...	...	...	counts	13 $\frac{1}{3}$
SPUN SILK	...	...	...	"	13 $\frac{1}{3}$
RAW SILK	(1000 yards per oz.)	...	...	"	700
"	(1000 yards per dram)	...	...	"	22·857
"	(Denier Scale)	...	...	"	396·15
LINEN	(ordinary)	...	...	"	37 $\frac{1}{3}$
WOOLLEN	(Yorkshire skein)	...	...	"	42·32
"	(West of England)	...	...	"	24 $\frac{7}{8}$
"	(Dewsbury)	...	...	"	700
"	(Bunch Count)	...	...	"	3 $\frac{1}{3}$
"	(Sowerby Bridge)	...	...	"	1·828
ABERDEEN	...	...	...	...	1 $\frac{2}{7}$ lb. yarn
STIRLING	...	...	...	...	23 $\frac{1}{3}$
GALASHIELS	...	...	...	...	56
HAWICK	...	...	...	...	60 $\frac{2}{3}$
AMERICAN	"Run"	...	...	...	7
"	"Grain"	...	...	...	12 $\frac{1}{2}$

These comparisons show at a glance the relative value of counts in the various systems, and also how much the unit of counts varies in different districts.

A further comparison may be made which for practical purposes will be more valuable than either of those already made, by showing the number of yards per lb., for 1's count in each of

the systems. This would of course show exactly the same relative value as does that in which 20's are taken, but the advantage it possesses is this, that in converting the counts of one system into the counts of another system, it is more readily done by reducing the relative values to their lowest terms. With a comparative table of this kind, showing the number of yards per lb. for 1's counts in each case, the whole series is practically reduced to their units of measurement, and should any two be required for conversion from one to the other, their terms can be further reduced, if they will permit of it, very readily.

Taking then 1's as the counts, the yards per lb. will be as follows:—

WORSTED	...	...	...	...	560
COTTON	...	...	...	...	840
SPUN SILK	...	...	...	...	840
RAW	..	(1000 yards per oz.)	...	...	16,000
..	..	(1000 yards per dram)	...	...	256,000
..	..	(Denier scale)	...	...	4,437.333 $\frac{1}{3}$
LINEN (ordinary)	...	...	...	...	300
WOOLLEN (Yorkshire skein)	...	...	...	...	256
..	..	(West of England)	...	...	320
..	..	(Dewsbury)	...	...	16
..	..	(Bunch Count)	...	...	55,760
..	..	(Sowerby Bridge)	...	...	20,480
ABERDEEN	...	...	...	...	14,400
STIRLING	...	...	...	...	480
GALASHIELS	...	...	...	...	200
HAWICK...	...	...	...	...	184 $\frac{1}{2}$ $\frac{6}{c}$
AMERICAN "RUN"	...	...	...	...	1,600
..	..	"Grain"	...	...	350

One curious feature must strike one in the comparison made here, and the one in which 20's is made the basis. In the silk scales, and in the Aberdeen, Sowerby Bridge, and Bunch Count

systems, 1's yarn contains more yards per lb. than 20's, whilst in all the other systems it contains less. It is generally recognised, that the higher the counts, the finer the yarn, but in these five systems it is the reverse; this simply arises from the fact, that in the majority of systems the counts are indicated by the number of hanks, skeins, leas, &c., which weigh a given weight, and consequently the more hanks are required to be equal to that weight, the finer the yarn must be; whereas in the five systems named, the counts are indicated by the weight of the hank or "spynkle," or a given number of yards, and consequently the higher the counts, the more the hank weighs, and therefore the heavier the thread. In making use of these tables of comparison, it will be necessary to bear this carefully in mind, otherwise serious mistakes might be made.

TO REDUCE THE COUNTS OF YARN IN ONE SYSTEM TO ITS EQUIVALENT COUNTS IN ANOTHER SYSTEM.

RULE I.—As the yards per lb. for 1's in one system is to the yards per lb. for 1's in another system, so is the counts of one to the counts of the other.\*

It will be evident that by taking 1's as a basis, the standard of comparison is handy and reliable; and by taking the yards per lb. and reducing them to their lowest terms, the calculation is made more easy. For instance, in dealing with worsted and cotton, when the yards per hank are 560 and 840 respectively, if the count is 1's, that means 1 hank per lb., and consequently is equal to 560 and 840 yards per lb. respectively; if it is required

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\*This rule will apply to all the systems given but those of the "dram" and "denier" scales in silk, and the Aberdeen scales, for the reasons given in p. 16 & 17.

to find the counts of one material which shall give a yarn equal to that of a given counts in the other material, it can be readily found, for 560 is to 840, as 2 is to 3, then, as 560 is to 840 or as 2 is to 3, so is the counts of cotton to its equivalent counts of worsted, or *vice versa*.

*Example.*—What counts of cotton is equal to 24's worsted?

As  $840 : 560$  or as  $3 : 2 :: 24 : 16$ .

Or 16's cotton is equal to 24's worsted; that is in 16's cotton there are 16 times 840 yards = 13,440 yards per lb., and in 24's worsted there are 24 times 560 = 13,440 yards per lb., therefore the weight of one yard, or any equal number of yards of each material is the same.

If changing from cotton to worsted then the proportion will be reversed thus:

As  $560 : 840$ , or as  $2 : 3 :: 16 : 24$ .

In dealing with the Yorkshire skein system of counting woollens the numbers 256 will be substituted for 840 or 560. Thus to find the counts of woollen, which would be equivalent to any counts of worsted, the proportion would be as 256 is to 560, or reduced to their lowest terms, as 16 is to 35, because 16 and 35 bear the same proportion to each other as 256 and 560. Thus as 16 is to 35 so is any counts of worsted to the counts of woollen which will give the same number of yards per lb.

*Example.*—What counts of woollen (Yorkshire skein) is equal to 20's worsted?

As  $256 : 560$ , or as  $16 : 35 :: 20 : 43\frac{3}{4}$ .

And if the counts of woollen be given to find its equivalent in worsted, the proportion will be reversed, thus:

As  $560 : 256$  or as  $35 : 16 :: 43\frac{3}{4} : 20$ ; so that the yards per lb. in those two counts will be the same.

This mode of working is much more simple and easy of application, in most cases, than taking the whole system or basis of counts into consideration; though in some instances in the course of the calculations given in this work the whole basis will be taken into account for the sake of conveying clearly the whole process of working to the mind, but the abbreviated method will also be given at the same time. Take for example the converting of the Galashiels into that of Yorkshire skein count. Reduced to its simplest form it would be as 200 is to 256, because that is the number of yards per lb. for 1's in each case, or reduced to their lowest terms as 25 is to 32. So that to find the counts of Galashiels yarn equal to 20's Yorkshire yarn, the statement would be as  $25 : 32 :: 20 : 25\frac{3}{8}$ . This is simplicity itself; but to take the whole basis of each system into account it will be  $\frac{1536 \times 24 \times 20}{6 \times 16 \times 300} = 25\frac{3}{5}$  or even shortened it will be  $\frac{256 \times 24 \times 20}{16 \times 300} = 25\frac{3}{5}$ ; thus how much more simple the first formula, and how much less liable to error in the working out of the figures.

ASCERTAINING THE COUNTS OF "FOLDED" YARNS, WHETHER THE YARN CONSISTS OF ONE MATERIAL OR MORE.

What is meant by folded yarns is the twisting of two or more threads together to form one thread. In most cases this is done for the purpose of producing a strong thread, which may be suitable for making fabrics of great strength, though it is sometimes done for the purpose of forming a fancy thread for ornamentation only. In any case strict attention should be paid to the counts of the yarn resulting from the combined

threads. When the threads which are twisted together are all of the same counts there is little difficulty in this respect, but where they differ in their respective counts, then the resulting counts differ very much. For instance, if two threads of 60's yarn in any material be twisted together, the counts of the two-fold would be half of 60's,—30's as already explained—but if a thread of 80's and one of 40's be twisted together, the resulting counts would not be 30's although it would appear that the 80's being finer and lighter, whilst the 40's is coarser and heavier than 60's, that one would compensate for the other. That such is not the case may be easily demonstrated. Take one hank of 60's worsted, the weight of that hank will be 4·266 drams ( $\frac{256}{60} = 4·266$ ), then two of those hanks twisted together would make one hank weighing 8·533 drams, and yarn of that weight per hank, will be equal to 30 hanks per lb. ( $\frac{256}{8·533} = 30$ ). Next to take the case of the 80's and 40's yarn. One hank of 80's will weigh 3·2 drams ( $\frac{256}{80} = 3·2$ ); and one hank of 40's will weigh 6·4 drams ( $\frac{256}{40} = 6·4$ ); and those two hanks twisted together would make one weighing 9·6 drams: and one hank of that weight would be equal to  $26\frac{2}{3}$  hanks per lb. ( $\frac{256}{9·6} = 26\frac{2}{3}$ ) so that the counts of the yarn resulting from the twisting together of 80's and 40's would be  $26\frac{2}{3}$ 's.

There are several methods of readily ascertaining the counts of folded yarns, one is by simple proportion.



RULE (2)—As the sum of the two counts is to the highest, so is the lowest of the two to the resulting counts.

*Example.*—As  $(80+40)=120$  is to  $80 :: 40 : 26\frac{2}{3}$ , the counts required.

Or if the two yarns are 50's and 40's to find the resulting counts.

As  $(50+40)=90 : 50 :: 40 : 22\cdot22$ , the counts required.

Another mode of stating the question, and which is just the same as the form of proportion given above,

$$\text{is } \frac{50 \times 40}{50+40} = 22\cdot22$$

Another method is as follows :

RULE (3).—Divide one of the counts (more conveniently the highest) by itself and by each other count, then by the sum of the quotient, and the last quotient will be the counts required.

*Example.*—To find the counts of 80's and 40's yarn, doubled.

$$80 \div 80 = 1$$

$$80 \div 40 = 2$$

—

$$80 \div 3 = 26\frac{2}{3} \text{ the counts required.}$$

$$\text{Or } 40 \div 80 = \cdot 5$$

$$40 \div 40 = 1$$

—

$$40 \div 1\cdot5 = 26\frac{2}{3}$$

*Example 2* — To find the counts of 50's and 40's yarn doubled.

$$50 \div 50 = 1$$

$$50 \div 40 = 1.25$$

---


$$50 \div 2.25 = 22.22,$$

Or  $40 \div 50 = .8$

$$40 \div 40 = 1$$

---


$$40 \div 1.8 = 22.22 \text{ the counts required.}$$

To give one more proof of the truth of the system, whichever particular method of working is adopted. Take two woollen yarns to twist together, and let the basis of calculation be the Yorkshire skein. Suppose the counts of each yarn to be 30's and 20's respectively, by the first method:—

$$\text{As } 30 + 20 = 50 :: 30 :: 20 : 12.$$

$$\text{As } \frac{30 \times 20}{30 + 20} = 12.$$

Or  $30 \div 30 = 1$

$$30 \div 20 = 1.5$$

---


$$30 \div 2.5 = 12.$$

Or  $20 \div 20 = 1$

$$20 \div 30 = \frac{2}{3} \text{ or } .66$$

---


$$20 \div 1\frac{2}{3} = 12.$$

Then further: by the Yorkshire skein count system, the number of yards per dram represents the counts, so that taking 20 yards of each count to twist together:—

20 yards of 20's would weigh	...	1 dram.
20     "     30's             "	...	$\frac{2}{3}$ "

---

20 yds. of the double thread would weigh  $1\frac{2}{3}$  "

and if 20 yards weighs  $1\frac{2}{3}$  drams, 12 yards would weigh 1 dram, so that the counts would be 12's.

### TWISTING DIFFERENT MATERIALS.

In many cases threads of different materials are twisted together for the purpose of producing fancy yarns. In such cases the two must be reduced to the same value, and the resulting counts found in one of the two systems. For instance, if worsted and silk be twisted together the resulting counts must be in either worsted or in silk counts. In most cases it is most convenient to reduce them both to the same denomination and then apply the rule given; or sometimes one formula to find the counts direct may be used.

In worsted and spun silk the relative counts are as 560 to 840, or as 2 to 3. Then, suppose the counts of the two yarns respectively are 30's worsted and 60's silk to bring the silk to the worsted denomination it would be as  $560:840::60:90$  or as  $2:3::60:90$ , because 60 hanks of 840 yards each are equal to 90 hanks of 560 yards each, and to find the counts resulting from the combinations it would be as  $(90+30)=120:90::30:22\frac{1}{2}$ , or the weight of the double yarn would be equal to  $22\frac{1}{2}$ 's worsted.

The counts might be found as follows, and this formula will comprise the whole question.

$$\text{As } \left( \frac{60 \times 840}{560} + 30 \right) : \left( \frac{60 \times 840}{560} \right) :: 30 : 22\frac{1}{2}$$

This is no doubt the correct method of stating the question, but the previous one is much simpler and more readily understood by persons not thoroughly conversant with figures.

If it is required to find the counts equal to

silk— though the usual practice is to find it in that of the heaviest material used—then bring the counts of worsted to that of the silk, thus :

$$\frac{30 \times 560}{840} \text{ or } \frac{30 \times 2}{3} = 20.$$

Then as  $(60 + 20) : 60 :: 20 : 15$ , or it would be equal to 15's silk counts.

Or by the other formula,

$$\text{As } \left( \frac{30 \times 2}{3} + 60 \right) : 60 :: \left( \frac{30 \times 2}{3} \right) : 15.$$

In the manufacture of fancy woollen yarns, woollen and silk twisted together are very frequently used, in such cases it is necessary to know what is the counts of the yarn resulting from such mixture. To find this, the rules given for worsted and silk will exactly apply, only substituting 256 (the drams, per lb., and consequently the yards per lb. for 1's woollen—Yorkshire skein) for 560, the yards per hank in worsted ; thus if we have 20 skein woollen, with a thread of 60's silk, to bring the silk to woollen denomination it would be as  $256 : 840 :: 60 : 196\frac{7}{8}$ , then as  $(196\frac{7}{8} + 20) : 196\frac{7}{8} :: 20 : 18\frac{54}{77}$ , the counts resulting.

If the silk used be organzine, as is often the case, then deal with it in exactly the same manner, finding the yards per lb., and reducing the whole to woollen counts ; the only difference will be that whether the "Denier" scale or the "dram" scale be used, they must be reduced to yards per lb.,—instead of using 840 the counts as in spun silk—and having found the relative value of the silk and woollen, they will be dealt with precisely as in other cases.

One matter connected with the production of

“folded yarns” must not be overlooked. In the process of twisting, a certain amount of shrinkage or “take up” will take place, that is when one thread is twisted round another the length of the doubled yarn resulting will not be quite equal to the length of each single yarn respectively, something will be lost in length by the fact of their twisting round each other. It is evident that if both threads are of the same diameter, the “take up” of each will be the same, because each will bend round the other in an equal degree, but if one thread is thick and the other thin there will be a difference in the take up of each respectively. For instance, if one is a thick woollen and the other a fine silk thread, the silk will wrap round the woollen because it has not the power to bend the woollen thread, and if it did, it would become embedded in it, consequently the woollen remains practically a straight thread while the silk thread is twisting round it, therefore a greater length of silk than woollen will be used in the production of a given length of yarn, and not only the counts resulting, but the cost of the yarn will be materially affected. The formulæ given here do not take that into account. It would be a difficult matter to lay down rules for determining this “take up,” it will vary so much. The relative counts of the yarn; the number of twists or turns per inch, and the relative tension of the two threads will all affect it, so that the manufacturer is thrown back upon data drawn from actual practice as to the amount of take up which will actually occur in the making of such yarns. Formulæ might be given, but they would be of too intricate a character to be of real practical value, and those already given, with an allowance for shrinkage based upon some practical knowledge will be found to meet all the requirements.

TO FIND THE COUNTS OF A YARN WHEN THREE OR MORE THREADS ARE TWISTED TOGETHER.

When three or more threads are twisted together, the readiest method of finding the counts is to divide one of the numbers by itself, and by each other in succession, and then by the sum of the quotients, thus if three threads of 80's, 60's, and 40's respectively are to be twisted together—

$$80 \div 80 = 1$$

$$80 \div 60 = 1\frac{1}{3}$$

$$80 \div 40 = 2$$

---


$$80 \div 4\frac{1}{3} = 18\frac{6}{13}$$

Or  $60 \div 60 = 1$

$$60 \div 80 = \frac{3}{4}$$

$$60 \div 40 = 1\frac{1}{2}$$

---


$$60 \div 3\frac{1}{4} = 18\frac{6}{13}$$

The question may be put in one complete formula, thus:  $\left(\frac{80 \times 60}{80 + 60} + 40\right) : 40 :: \left(\frac{80 \times 60}{80 + 60} : 18\frac{6}{13}\right)$

In other words, it is finding the counts resulting from two of the three threads, and then the counts of those two with the third, thus:—80's and 60's will give  $(80 + 60) : 80 :: 60 : 34\frac{2}{7}$ , and  $(34\frac{2}{7} + 40) : 40 :: 34\frac{2}{7} : 18\frac{6}{13}$ .

It is obvious that this latter mode of proceeding is less convenient, and not more accurate than the previous one, and therefore is not the one which might be adopted in practice, more especially as more figures are used, more labour entailed, and consequently greater liability to error and loss of time. Whatever number of threads are put together, the rule will apply, and if the threads are of different materials, reduce them all to the same value—by preference to that which is predominant—and proceed in the same manner.

TO FIND THE COUNT OF A THREAD, WHICH TWISTED WITH ANY KNOWN THREAD WILL PRODUCE ONE OF A GIVEN COUNT.

In many cases in making folded yarns, it is necessary that the counts resulting from the twisting of two threads whether of the same or different materials should be a given counts; for instance, it may be said it is required to twist with a thread of 20's worsted, another thread of worsted of such counts that the two together shall be equal to 8's; or it may be that it is required to twist together worsted and cotton, worsted and silk, or woollen and cotton, or any two materials, then it becomes necessary to find what thread, along with the given one, will produce a thread equal to the count required. This is simply a reversal of the process adopted to find the counts of any two known threads twisted together, and will be found by the following.

RULE (4).—Divide the product of the given and required counts by the given minus the required counts of yarn.

*Example.*—It is required to twist with a thread of 20's another thread, which together shall make one equal to 8's.

$$\frac{20 \times 8}{20 - 8} = 13\frac{1}{3}$$

Thus it will be found that the counts of the second thread will require to be equal to  $13\frac{1}{3}$ , and to prove that this is correct by rule (2).

$$\frac{20 \times 13\frac{1}{3}}{20 + 13\frac{1}{3}} = 8's, \text{ the counts sought to be produced.}$$

These rules are really based upon what is known as the doctrine of combinations, although not expressed in the usual form of combinations,

and the calculations are more easily worked by methods given here than by the ordinary system of combinations. It is, however, desirable that the system should be understood. Put in general terms, when two threads, A B, are twisted together it will be

$$\frac{A \ B}{A+B} = C, \text{ therefore } \frac{A \ C}{A-C} = B, \text{ and } \frac{B \ C}{B-C} = A.$$

If this is true of two threads it must be equally true of three or more threads, therefore

$$\frac{A \ B \ C}{(AB) + (AC) + (BC)} = D, \text{ and that being so, if two}$$

of the threads and the resulting thread by the combination of three are given to find the third thread of the combination it must be reversed, that is, the products of the several combinations must be subtracted from each other instead of being added together, thus if A, B and D, are given to find C,

$$\text{then } \frac{A \ B \ D}{(AB) - (AD) - (BD)} = C. \text{ To prove that this}$$

is so assume that three threads of 40's, 30's and 20's respectively are to be twisted together, then by the method already given

$$40 \div 40 = 1$$

$$40 \div 30 = 1\frac{1}{3}$$

$$40 \div 20 = 2$$

$$\text{and } 40 \div 4\frac{1}{3} = 9\frac{3}{13}$$

And by the method just indicated it will be

$$\frac{40 \times 30 \times 20}{(40 \times 30) + (40 \times 20) + (30 \times 20)} = 9\frac{3}{13}$$

Now assume that the 40's and 30's yarn are given and it is desired to combine with them another yarn which will produce one of  $9\frac{3}{13}$  counts, then

$$\frac{40 \times 30 \times 9\frac{3}{13}}{(40 \times 30) - (40 \times 9\frac{3}{13}) - (30 \times 9\frac{3}{13})} = 20$$

thus proving that the method is correct.



This, of course, must be equally true for any number of threads in combination, thus for four threads it would be

$$\frac{A B C D}{(ABC) + (ACD) + (ABD) + (BCD)} = E,$$

the combinations always being one less than the total number of threads employed. Then again, suppose that three of the threads and the resulting thread are given to find the fourth, it

will be  $\frac{A B C E}{(ABC) - (ABE) - (ACE) - (BCE)} = D$ , and the same for any other thread. If A is the thread to be found then

$$\frac{B C D E}{(BCD) - (BCE) - (BDE) - (DCD)} = A,$$

and so on.

It will be obvious from this that the rule must apply to any number of threads.

In the event of dealing with two different materials, or two materials calculated on different bases, of course the same expedient must be resorted to as already shown, of reducing both to the same denomination or value, and proceeding exactly as above, this reduction may be made separately, or by using formula similar to that given at page 23.

IN TWISTING TOGETHER TWO THREADS OF DIFFERENT COUNTS, TO FIND THE WEIGHT OF EACH REQUIRED TO PRODUCE A GIVEN WEIGHT.

RULE (5).—Find the counts resulting from the two threads, then, as the counts of one thread is to the resulting counts, so is the total weight to the weight required of that thread.

Suppose, for example, that the two threads are 40's and 16's respectively, of any material, or in

any system of counts, then the counts of yarn resulting from those two threads would be  $(40+16):40::16:11\frac{2}{7}$ , then  $11\frac{2}{7}$ 's being the counts of the doubled thread, to find the quantity of each required to produce, say 100 lbs. of doubled yarn, it would be:—

As  $40:11\frac{2}{7}::100:28\frac{4}{7}$  lbs. of 40's yarn required, and

As  $16:11\frac{2}{7}::100:71\frac{5}{7}$  lbs. of 16's yarn required.

Or the respective weights may be found by a more simple and easy rule, as follows:—

RULE (6).—As the sum of the two counts is to one of the counts, so is the total weight to the weight required of the other counts.

Thus, taking again the two counts already used, viz:—40 and 16, and it is required to produce 100 lbs., what weight of each will be required? Thus,

As  $(40+16)=56:40::100:71\frac{2}{7}$  lbs. the weight of 16's required, and

As  $(40+16)=56:16::100:28\frac{4}{7}$  lbs. the weight of 40's yarn required.

Bearing in mind that as counts increase, weight decreases, and *vice versa*, this rule, though at first sight contradictory, will readily explain itself.

TO FIND THE AVERAGE COUNTS, WHEN ANY NUMBER OF YARNS OF DIFFERENT COUNTS ARE USED IN THE SAME CLOTH.

This is very useful for a variety of purposes, when fancy cloths are being made which contain a variety of yarns of different counts. It may, for instance, occur that a cloth is to be produced which will contain several counts of yarn, and it is desired to find the actual weight. By the ordinary methods of working it would be necessary to find the weight of each yarn separately for a given width and length of piece, and then add the

several weights together. Instead of doing so, the average counts of all the yarns may be found, and then the weight obtained by one calculation as though one yarn only were being used.

It is practically another application of the Rule given at page 26, for finding the counts resulting from several threads twisted together, with the simple difference that instead of finding the counts of one thread, consisting of all the several threads, it is finding the average counts of all the several threads.

*Example.*—Suppose a cloth consists of alternate threads of 16's and 40's yarn in any system of counts, it is required to find the average counts. By Rule (2) page 21, if the two threads were made one, the counts of that thread would be  $\frac{16 \times 40}{16 + 40} = 11\frac{3}{7}$ , but there is not one thread resulting, each thread retains its individuality, therefore the average weight of the threads is half that of a single thread formed by the two, and therefore double the counts, or equal to  $22\frac{6}{7}$ .

For this purpose, then the following will be the Rule:—Find the resulting counts as by Rule (2), or (3), then multiply by the number of threads in the pattern.

*Example 2.*—A cloth is made with two threads of 40's and one of 16's yarn: what is the average counts?

$$\begin{aligned} \text{By Rule (3):—} & 40 \div 40 = 1 \\ & 40 \div 40 = 1 \\ & 40 \div 16 = 2\frac{1}{2} \end{aligned}$$

---


$$40 \div 4\frac{1}{2} = 8.88.$$

Then,  $8.88 \times 3$  threads = 26.66 or  $26\frac{2}{3}$ , the average counts of the yarn.

The process may be slightly shortened by the following:—

RULE (7).—Divide any count—the highest by preference—by itself, and each of the others in succession: then divide the product of these counts multiplied by the number of threads in the pattern, by the sum of the several quotients multiplied by the number of threads of each respectively; the last quotient will be the average counts sought.

*Example.*—A cloth consists of four thread of 80's, two of 40's, and one of 16's; what is the average counts?

$$\begin{array}{r} 80 \div 80 = 1 \times 4 \text{ threads} = 4 \\ 80 \div 40 = 2 \times 2 \quad \text{,,} = 4 \\ 80 \div 16 = 5 \times 1 \quad \text{,,} = 5 \\ \hline \qquad \qquad \qquad 7 \qquad \qquad \qquad 13 \end{array}$$

Then there are 7 threads and  $\frac{80 \times 7}{13} = 43\frac{1}{3}$ .

As a proof of the truth of this Rule: Suppose the above material to be cotton; find the weight of one hank of each counts, then find the weight of an average hank with the threads in the proportions given, and see what would be the counts of a hank of that weight.

One hank of 80's weighs 3.2 drams

One    ,,   40's    ,,   6.4    ,,

One    ,,   16's    ,,   16    ,,

Then as there are four threads of 80's, four hanks would weigh    ...    ...    12.8 drams

Two threads of 40's, two hanks would weigh    ...    ...    ...    12.8    ,,

One thread of 16's, one hank would weigh    ...    ...    ...    16    ,,

The sum of these weights will be 41.6

and 41.6 drams, divided by 7 hanks, gives the weight of one hank 5.93 drams  $\left(\frac{41.6}{7}=5.93\right)$  and the counts of one hank of that weight will be  $\frac{256}{5.93}=43\frac{1}{3}$ , therefore proving the accuracy of the rule.

In all these examples of "folded yarns" no account has been taken of shrinkage or "take up" in twisting, so that, as already pointed out, it must be borne in mind in determining the actual quantities.

In dealing with yarns formed from two threads of different counts, the probabilities will be that they are also of different materials, and consequently then determined on a different basis, as woollen and silk, or worsted and silk, and so on; in such cases the rule given to find resulting counts will apply, *viz.*, reduce both to the same value or denomination, and then determine the quantity of each separately.

#### THE COST OF "FOLDED YARNS."

Another question connected with folded yarns is the determination of the cost of a yarn composed of two threads of different value, and at the same time probably of different counts and materials. In such cases, it will really resolve itself into a question of averages, for instance, if a thread of 10's and a thread of 40's be twisted together, 40lbs. of 10's and 10lbs. of 40's would be equal to each other in length, if both are of the same denomination, and if the value per lb. of the 10's be 10d., and if the 40's be 40d., then 40lbs. at 10d. and 10lbs. at 40d. will give an average of 16d., or

to put the question in a more complete form, if 40's yarn and 10's yarn are to be put together, they will produce a yarn equal to  $(40+10):40::10:8$  or 8's yarn, then if 50lbs. of this yarn is to be produced, it will be

As  $40:8::50:10$ : or 10lbs. of 40's yarn will be required.

And as  $10:8::50:40$  or 40lbs. of 10's yarn will be required.

Then 40lbs. at 10d. equals 400d., and  
 10lbs. at 40d. equals 400d., and  
 $400+400=800$ , for 50lbs. equals 16d. per lb.;  
 then for simplicity it may be stated as a general

**RULE. (8).**—Multiply the highest counts by the price of the lowest, and the lowest counts by the price of the highest, and divide the sum of the products by the sum of the counts.

*Example.*—A 36's yarn costs 42d. per lb., and a 12's yarn costs 14d. per lb.; what is the cost of a yarn composed of the two twisted together?

$$36 \times 14 = 504$$

$$12 \times 42 = 504$$

$48$        $1008$  and  $1008 \div 48 = 21d.$ , the cost of the folded yarn.

If the yarns are of different materials and the counts are reckoned on a different basis, then reduce them both to the same value or denomination, and proceed in the same manner as before, for example, a 20 skein woollen is twisted with a 60's spun silk, the value of the woollen is  $2/8$  per lb., and the silk 12/- per lb.; what is the cost of the resulting yarn?

60's silk is equal to  $196\frac{7}{8}$  woollen ; then

$$20 \times 144d. = 2880d., \text{ and}$$

$$196\frac{7}{8} \times 32d. = 6300d., \text{ the sum of the two equals}$$

$216\frac{7}{8}$  and  $9180$  and  $9180d. \div 216\frac{7}{8} = 42\frac{11}{4}\frac{1}{7}d.$   
per lb., or  $3/6\frac{11}{4}\frac{1}{7}d.$  per lb. of the resulting yarn.

Take into account the amount of shrinkage or "take up" which will occur in the silk yarn twisting round the woollen, and the cost of the yarn is obtained at once.

This really, as is the case in determining the counts of folded yarns, is based upon the doctrine of combinations, but there is the question of cost added to it. For instance, when two threads, say A, B, are twisted together to find the resulting counts, the formula used is  $\frac{A \ B}{A+B}$  = the resulting counts. Now if the values of the two yarns respectively be taken into account, A is multiplied by the price of B, and B by the price of A, and the sum of the products is divided by the sum of the counts, or A+B, therefore the formula must be, assuming Z to be the price of A, and Y the price of B— $\frac{AY+BZ}{A+B}$ . This is strictly in accordance with

the rule given. For the purpose of showing that this is true, take the same counts and values, then  $\frac{(36 \times 14) + (12 \times 42)}{36 + 12} = 21d.$  the cost of the folded yarn.

If this is true of two threads, and the doctrine of combinations holds good throughout, it must be equally true of three, or any number of threads.

Suppose for example that it is desired to combine three threads of different counts and different values, as say a 60's, 40's, and 20's, of the respective values of 32d., 24d., and 16d., and it is

required to find the value of the resulting yarn. Following the Rule (8) this may be found by first finding the value of the combination of any two of the three, and then the value of the thread resulting from those two with the third, thus: first to combine the 60's and the 40's—

$$60 \times 24 = 1440$$

$$40 \times 32 = 1280$$

$100 \div 2720 = 27.2$ d. the value of this combination, and  $\frac{60 \times 40}{60 + 40} = 24$ 's the counts of the combination.

Then to combine this resulting thread with the third, it will be treated as a combination of a thread of 24's, worth 27.2d., with a thread of 20's, worth 16d., and by the Rule—

$$24 \times 16 = 384$$

$$20 \times 27.2 = 544$$

$44 \div 928 = 21\frac{1}{11}$ d. the value per lb. of the resulting yarn.

This is a simple, and comparatively easy mode of working, and will readily find the cost of the combination of any number of threads, thus if there be four threads, two combinations of two each may be made, and then the resulting combinations found.

But this may be reduced to a general formula, and which may be applicable to any number of threads. Take for example the three just given, and to express them in general terms—

Let A B C, &c., represent counts, and Z Y W, " " " their values respectively, then to carry out the combination as just given the formula would be

$$\frac{\left(\frac{A Y + B Z}{A + B} \times C\right) + \left(W \times \frac{A B}{A + B}\right)}{\left(\frac{A B}{A + B} + C\right)}$$



and this reduced to its simple form would be  $\frac{A B W + A C Y + B C Z}{A B + A C + B C} =$  the value of the resulting combination. Or, in other words, two of the three threads together with the price of the third, and divided by those two threads in all the combinations possible, will find the value of the resulting combination.

To show that this is true take the counts and values given in the last example, then

$$\frac{(62 \times 40 \times 16) + (60 \times 20 \times 24) + (40 \times 20 \times 32)}{(60 \times 40) + (60 \times 20) + (40 \times 20)} = 21\frac{1}{11}$$

In any combinations of any number of threads this must apply always for a numerator, combining all the threads, minus one, with the price of that one in all the various orders, and for a denominator combining all the various threads in the same order, but without their values, thus, let A B C D be the counts of four threads, and Z Y W U be their respective values, then to find the value of the combinations it will be

$$\frac{ABCU + ABDW + ACDY + BCDZ}{ABC + ABD + ACD + BCD}$$

Then let the counts be 80's, 60's, 50's, and 40's and their respective values 40d., 36d., 32d., and 24d., and the combination will be

$$\frac{(80 \cdot 60 \cdot 50 \cdot 24) + (80 \cdot 60 \cdot 40 \cdot 32) + (80 \cdot 50 \cdot 40 \cdot 36) + (60 \cdot 50 \cdot 40 \cdot 40)}{(80 \cdot 60 \cdot 50) + (80 \cdot 60 \cdot 40) + (80 \cdot 50 \cdot 40) + (60 \cdot 50 \cdot 40)} = 31 \cdot 55d.$$

the value of the combination. To prove that this is true take the combinations in twos. For convenience combine the 80's with the 60's, and the 50's with the 40's, then the two resulting threads together; though of course it must be equally true of any combination of pairs.

Then by the rule given for combining two threads.

$$80 \times 36 = 2880$$

$$60 \times 40 = 2400$$

$$\begin{array}{r} \text{---} \\ 140 \div 5280 = 37.71 \text{ the cost} \end{array}$$

of the first combination, and  $\frac{80 \times 60}{80 + 60} = 34.28$  the counts.

$$\text{And } 50 \times 24 = 1200$$

$$40 \times 32 = 1280$$

$$\begin{array}{r} \text{---} \\ 90 \div 2480 = 27.55 \text{ the cost} \end{array}$$

$$\text{And } \frac{50 \times 40}{50 + 40} = 22.22 \text{ the counts of the}$$

second combination. Next, to combine the two together it will be

$$22.22 \times 37.71 = 837.8162$$

$$34.28 \times 27.55 = 944.4140$$

$$\begin{array}{r} \text{---} \\ 56.50 \div 1782.2302 = 31.55. \end{array}$$

Thus proving that the two methods must of necessity produce the same result, no matter how many threads are combined.

In the latter method there is, no doubt, a liability to error in having to deal with so many fractions, but on the other hand, to one not in the habit of dealing with combinations it is more easily remembered than when embraced in one complete formula.

#### TO FIND THE COST OF MIXED YARNS.

The term "mixture yarn" may be used in a double sense, either that the yarn is composed of fibres of different colours, or of fibres of different qualities or materials; in all classes of textile goods yarns are made of fibres of different qualities and values; in many cases the object is to produce an article at a comparatively cheap



No matter how many materials, or what is the relative quantity of each, of course, exactly the same rule will apply.

In the second case, or what is termed ALLIGATION ALTERNATE, the rates or values of the simple quantities are given, and the object is to find the quantities of each which must be used to produce an article which may be sold at a given price. For instance it may be necessary to determine what quantity of each of the wools given to illustrate the first case will produce a mixture to cost  $19\frac{3}{4}$ d. per lb., instead of determining what will be the value of a mixture consisting of the two in given proportions, in that case the following will be the

RULE (10) 1st.—Place the respective values of the simple parts under each other, and the average rate desired to the left of them,

$$\text{thus, } 19\frac{3}{4} \left\{ \begin{array}{l} 22 \\ 16 \end{array} \right.$$

2nd.—Link a greater and a less value than the desired average together, thus,  $19\frac{3}{4} \left\{ \begin{array}{l} 22 \\ 16 \end{array} \right.$

3rd.—Find the difference between each value and the desired average, and place it *opposite to the value to which it is linked*, thus,  $19\frac{3}{4} \left\{ \begin{array}{l} 22 \\ 16 \end{array} \right. \begin{array}{l} 3\frac{3}{4} \\ 2\frac{1}{4} \end{array}$ . The differences so found will be the answers required.

In this example there are but two values, and the quantity of each required is found opposite its value, so that  $3\frac{3}{4}$ lbs. at 22d. and  $2\frac{1}{4}$ lbs. at 16d. will be required; then to prove that this is true—

$$3\frac{3}{4} @ 22d. = 82\frac{1}{2}d.$$

$$2\frac{1}{4} @ 16d. = 36d.$$

and 6lbs. for  $118\frac{1}{2}d. = 19\frac{3}{4}d.$ , the value required.

And the quantities  $3\frac{3}{4}$  and  $2\frac{1}{4}$  respectively, bear the same proportion to each other as do 5 and 3; thus  $3\frac{3}{4}:2\frac{1}{4}::5:3$ , thus proving the truth of the proposition.

But Alligation, whether alternate or otherwise, is not necessarily confined to questions dealing with two quantities or values, but it may deal with any number, and in so doing, in many cases, the relative quantities may be considerably varied, yet producing the same average value. Take this for example:—Four materials of the respective values of 6d., 10d., 16d., and 20d. are required to be mixed together in such quantities as to produce a mixture worth 14d.; then

$$14 \left\{ \begin{array}{l} 6- \\ 10- \\ 16- \\ 20- \end{array} \right. \begin{array}{l} 2 \\ 6 \\ 8 \\ 4 \end{array} \begin{array}{l} \text{at } 6=12 \\ \text{,, } 10=60 \\ \text{,, } 16=128 \\ \text{,, } 20=80 \end{array}$$

and 20 for 280d.=14d. each.

Then further:

$$14 \left\{ \begin{array}{l} 6- \\ 10- \\ 16- \\ 20- \end{array} \right. \begin{array}{l} 6 \\ 2 \\ 4 \\ 8 \end{array} \begin{array}{l} \text{at } 6=36 \\ \text{,, } 10=20 \\ \text{,, } 16=64 \\ \text{,, } 20=160 \end{array}$$

and 20 for 280d.=14d. each.

So that it will be seen that the relative quantities of the different values may be varied and yet obtain the same average resulting.

In some cases there may not be the same number of values above or below the average required, in such cases one number may be coupled to several, and the sum of the differences added together, thus for

*Example.*—Three materials of the respective values of 10d., 16d., and 20d. are required to be

mixed together to produce a mixture worth 18d. ; what quantities of each are required ?

$$18 \left\{ \begin{array}{l} 10 \text{---} \\ 16 \text{---} | \\ 20 \text{---} | \end{array} \right. \begin{array}{l} 2 \text{ at } 10 = 20 \\ 2 \text{ ,, } 16 = 32 \\ 8 + 2 = 10 \text{ ,, } 20 = 200 \end{array}$$

and 14 for 252 = 18d. each.

*Example 2.*—Four materials of the respective values of 8d., 10d., 15d., and 22d., are required to be mixed together to produce a mixture worth 17d. ; what quantities of each are required ?

$$17 \left\{ \begin{array}{l} 8 \text{---} \\ 10 \text{---} | \\ 15 \text{---} | \\ 22 \text{---} | \end{array} \right. \begin{array}{l} 5 \text{ at } 8 = 40 \\ 5 \text{ ,, } 10 = 50 \\ 5 \text{ ,, } 15 = 75 \\ 9 + 7 + 2 = 18 \text{ ,, } 22 = 396 \end{array}$$

and 33 for 561 = 17d. each.

The third case is ALLIGATION PARTIAL, and deals with cases where *one* of the quantities and the prices of the others are given to find the rest.

RULE (II).—Place, link, and find the quantities as in Alligation Alternate, then, as the difference opposite the quantity or value given is to each difference, so is the quantity given, to each quantity required.

*Example.*—A spinner has a pack (240lbs.) of wool, worth 22d. per lb., and desires to mix it with materials worth respectively 10d. and 16d. per lb. and to produce a mixture worth 15d. ; what quantity each of that at 10d. and 16d. must be used ?

$$15 \left\{ \begin{array}{l} 10 \text{---} \\ 16 \text{---} | \\ 22 \text{---} \end{array} \right. \begin{array}{l} 7 + 1 = 8 \\ 5 \\ 5 \end{array}$$

then as

$$5:5::240:240 \text{ and } 240 \text{ at } 22d. = 5280$$

$$5:5::240:240 \text{ and } 240 \text{ at } 16d. = 3840$$

$$5:8::240:384 \text{ and } 384 \text{ at } 10d. = 3840$$

and 864 for 12960d. = 15d. each.

Whatever number of values there may be, and whatever their differences, the rule will equally apply. In a large number of cases in actual practice, this rule will be of great value and service.

The fourth case, ALLIGATION TOTAL, is used when the whole quantity, the average value, and the price of the simple quantities of which the mixture is to consist are given; to find the quantities at each price which must be used. This case is based upon the following:—

RULE (12).—Place, link, and find the differences as in case 2; then the *sum* of the differences is to *each* difference, as the total quantity given is to the quantity required of each value.

*Example.*—It is required to make a mixture of 500lbs. of wool, three qualities are to be used of the respective values, 10d., 15d., and 21d, the value of the mixture to be 16d.; what quantity of each will be required?

$$\begin{array}{r}
 16 \left\{ \begin{array}{l} 10 \text{---} \\ 15 \text{---} \\ 21 \text{---} \end{array} \right. \begin{array}{l} 5 \\ 5 \\ 6+1=7 \end{array} \\
 \hline
 17
 \end{array}$$

Here the differences are found as in the previous case, and find their sum 17; then

$$\begin{array}{l}
 \text{As } 17:5::500:147\frac{1}{7} \\
 17:5::500:147\frac{1}{7} \\
 17:7::500:205\frac{1}{7} \\
 \hline
 500
 \end{array}$$

And to prove the accuracy take

$$\begin{array}{r}
 147\frac{1}{7} \text{ lbs. at } 10 = 1470\frac{10}{7} \\
 147\frac{1}{7} \text{ ,, } 15 = 2205\frac{15}{7} \\
 205\frac{1}{7} \text{ ,, } 21 = 4323\frac{21}{7} \\
 \hline
 \end{array}$$

and 500lbs. for 8000d. = 16d. per lb.

These rules will apply to all mixtures, and will be found very handy in practice, as they save all experiment or trial, giving the results sought at once, and with certain accuracy. Although the illustrations given here nominally are for wool, they are equally applicable to all materials. The word wool, and the particular values taken, are merely to convey to the mind some definite application, and cotton, silk, or anything else might have been used equally well, or even the mixture of two fibres of different qualities. The whole question is one of values, and consequently the rules once laid down may be used for anything.

#### RELATIVE DIAMETER OF THREADS.

The next question connected with threads is the relative diameter of threads of different counts, and as will be shown in a later stage of this work, this question has a material influence upon the structure of cloths, and the alteration of weights and qualities.

There is some little difficulty in putting this question clearly before the reader, more especially if he be of a non-mathematical turn of mind. The first question to consider is, what is meant by the counts of yarn? In speaking of counts the weight of the thread is indicated, as has been already shown, that is, a given number of yards of yarn weighing a given weight are equal to a given count, consequently the count, so called, is a clear indication of the solidity or weight of the thread, and threads of similar counts have similar weights or solidities. If that is so, then the sectional areas of such threads will be similar, and being similar, the question naturally follows, what will be the relative sectional areas of threads of different weights or counts.

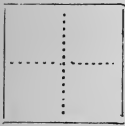
Suppose for a moment that threads are left aside, and the areas of circles simply are dealt



with for the purpose of making the matter as clear as possible. It is said that the areas of circles differ as the squares of their diameter, and therefore the diameters differ as the square roots of the areas. For the purpose of illustrating this,



A



B



C



D

Suppose the two squares *a. b.* on accompanying plate having their sides relatively 1 and 2 inches, the square *a* will cover an area of one square inch, and the square *b* though having its sides two inches in length, will cover an area of four square inches, as shown by the dotted line.

Then what applies to squares applies equally to circles. Take the two circles *c. d.*, their diameters are to each other as 1 to 2, but their areas are to each other as 1 to 4, exactly as in the case of the squares *a* and *b*, then this will show conclusively that the areas of circles are to each other as the squares of their diameters, and therefore that the diameters are to each other as the square roots of the areas.

Now in speaking of the counts of yarn, as has already been shown, the counts indicate the weight or solidity, or the word "area" or "sectional area" may be substituted for either of those terms, that is, having made a section of threads of known counts, the areas occupied by such sections will be to each other directly as their counts, then it necessarily follows, that their diameters will be as the square roots of such counts, and the

**RULE (13).**—*The diameters of threads vary as the square roots of their counts*

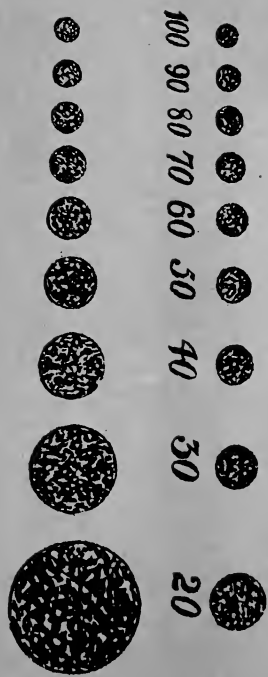
must therefore be true in all cases of similar threads, that is, threads made from the same

material and of similar structure, and with a similar number of twists<sup>o</sup> per inch.

Mistakes are very frequently made in the production of fabrics, in consequence of this rule not being observed, either through ignorance or carelessness, and in many cases, mistakes of a very serious character; threads are often treated as if their diameters differed directly as their counts. For the purpose of showing clearly how serious such mistakes may be, take the annexed diagram, in which the *real* and the *commonly supposed* relative diameter of threads are shown from 100's to 20's. The series of sections marked *a*, show the relative diameters of threads, calculated on the basis of the square roots of the counts which is of course their true basis, and the series marked *b*, show them in the direct ratio of their counts. It will be at once seen that there is a very great difference between the two, and that anyone judging the counts of yarns by comparison, unless he takes carefully into account what is the real difference, may easily make the most serious mistakes.

So as to show the reader the basis upon which this diagram has been worked out, it will be perhaps as well to explain what are the actual dimensions taken, otherwise there would be nothing to demonstrate the truth or untruth of the proposition. In the first place, a large diagram was prepared, in which the diameter of a thread of 100's was taken as being 2 inches. In the series *a*, or the true relative diameters, each diameter was calculated from the 2 inches, on the basis of the square roots of the numbers, to the 100th part of an inch, and the circle drawn accurately to that calculation, so that relatively the diameters are as nearly true as they can possibly be; the series *b*, are in the same

100 90 80 70 60 50 40 30 20





manner drawn in the direct ratio of the counts, then the whole diagram is reduced to its present size by photography, so that the truth of the first drawing on a large scale is preserved, and consequently the relative diameters are as nearly true as they can possibly be presented to the eye.

Too much stress cannot be laid upon the necessity of both the student and the manufacturer paying attention to this question, and making himself thoroughly familiar with it, as the whole question of the proper structure of fabrics, and the alterations in weights and other considerations are in a very great measure dependent upon it, as will be shown in subsequent portions of this work.

#### THE TWIST OF YARNS.

The question of the twist of yarns is entirely dependent upon the rule which has just been laid down respecting their relative diameters, that is, if it is desired to produce threads of similar character but of different counts, the number of turns per inch will be determined by that rule. Suppose for example, that a thread, say of 20's yarn in any material has 15 turns per inch, and it is required to produce a similar thread in 30's; what number of turns or twists per inch will give a similar thread? Seeing that the power of the twist upon the yarn will vary inversely, as the square of the diameter of the thread, or in other words, in the inverse ratio of the sectional area of

the thread, it will be as the  $\sqrt{20} : \sqrt{30} :: 15 : x$ , or as  $20 : 30 :: 15^2 : x^2$ , which will be

$$\frac{30 \times 15 \times 15}{20} = 337, \text{ the square}$$

root of which is  $18.3+$ ; therefore a 30's thread to be equal to a 20's thread having 15 twists per inch, must have 18.3 twists per inch.

In the twisting of threads of unequal diameters, as woollen, &c., this matter is of some importance as accounting in some degree for the inequalities being as it were magnified; this is accounted for by the fact, that as the twist is being put in the thread in the process of spinning, it will exert more power over the thin than the thick portions of the thread, and as the area of the circle varies as the square of the diameter, the power of the twist over the different portions of the thread will be in direct ratio to the sectional area of the thread. Then in determining the twists or turns to be put in a yarn of one counts to be equal to a yarn of another counts, it will be necessary to observe the

RULE (14.)—As a square root of one count is to the square root of another count, so is the turns or twists per inch in one yarn to the required twists per inch in the other yarn. Or

As one count is to the other counts, so is the twists squared in one yarn to the twists squared in another yarn.

*Example.*—A 40's yarn has 20 twists per inch; what twist will be required in a 60's yarn to be of the same character.

$$\text{As } \sqrt{40} : \sqrt{60} :: 20 : x = 24\frac{1}{2} \text{ nearly;}$$

$$\text{Or as } 40 : 60 :: 20^2 : x^2 = 24\frac{1}{2} \text{ nearly.}$$

In spinning cotton and some other materials certain empirical rules are laid down, which approximate somewhat to truth, but the foregoing is the only safe rule to work by for absolute accuracy.

## SETT CALCULATIONS.

The subject next in importance to the counts or numbering of yarns in Textile Calculations is that of "setts," or the method of indicating the pitch or fineness, or distance apart of the warp threads of which a piece of cloth is composed; these threads are separated or distributed by the reed or sley, and consequently the term "sett of the reed" is commonly employed, which simply means the number of threads in a given space in the cloth; as, the number per inch, per foot, or to any other unit of measurement.

To anyone uninitiated in the mysteries of "sett" systems, it would seem as if the simplest and most reliable method of working would be to take the ordinary unit of measurement, one inch, and indicate the sett or fineness of the cloth by the number of threads contained in that space. No doubt this would be a most rational course, but customs which seem to have prevailed in manufacturing districts, have become established, and these customs have been made by degrees the basis of the system upon which they work, consequently scarcely any two districts will be found to have the same sett basis, and the calculation of material required to make a piece of cloth in one district will be very different in its details from a calculation made for the same cloth in another district, although of course, the ultimate result would be the same in both cases.

Such being the case, it will be necessary to examine the sett system in a number of different districts, so as to discover upon what basis they are arranged, and then to consider their practical application in the calculation of a piece of fabric.

Then, what is the sett? It has been already said that the sett indicates the pitch, or distance apart of the warp threads, as they are separated or distributed over the fabric by the reed or sley in the process of weaving.

For the purpose of showing as clearly as possible the diversity which exists in the sett systems, Lancashire alone may be cited, for in that county it may be said that almost every village has its own system, and in some of the large towns they are not confined to one system, but have several.

The most rational of all these is what is known as the STOCKPORT SYSTEM, and which is based upon the number of "dents" or splits per inch in the reed, and it is gratifying to find that this system is being extensively adopted in other districts. What is known as the BOLTON SETT, is based upon the number of "beers" of 40 ends each in  $24\frac{1}{4}$  inches, and it will be seen that many districts have a similar basis, but using different widths, or a different number of ends per beer.

In a little work, "A useful guide to the manufacturing of cotton and mixed goods," the Preston system is given as being based upon the number of beers of 20 dents each in 34 inches.

In BLACKBURN the standard is 45 inches, and 20 dents per beer. In "RADCLIFFE and PILKINGTON the reeds are counted different ways, but as a rule, they are counted so many dents per inch. In the first place there are a few reeds that are counted by 19's, that is 19 dents, in place of 20, and there is one which is called a 44 reed, which is 44 beers in 36 inches," and again he says, "In Manchester the reeds for silk and fine dress goods are generally counted so many dents in 36 inches, that is, they would call a reed with 50 dents in one inch an 1,800 reed."



This latter system is somewhat similar to the SCOTCH SYSTEM, which is based upon the number of dents in 37 inches, so that an 1,800 reed would mean 1,800 dents in 37 inches.

In the Tweed trade of the south of Scotland the sett is based upon the number of porters contained in 37 inches, and as in some of the other systems the number of threads in a split is two, unless otherwise expressed.

In this as in some other systems a "reed gauge" is used for testing or ascertaining the sett of the reed. That for the Bradford system is one-twentieth of 36 inches, or  $\frac{36}{20} = 1\frac{4}{5}$  and the Scotch Tweed will be  $\frac{37}{20} = 1\frac{17}{20}$ .

In some of the silk manufacturing districts the sett is indicated by the number of dents or splits of the reed in the width of the piece, and the ends through each split stated at the same time. This system of course at once indicates the total number of ends in the whole piece, thus, there may be 1,200 dents or splits in 18 inches, and eight threads in each split, it would then be called a "twelve hundred eight thread, eighteen inches," or if the piece was 24 inches wide, it might still be a 1,200 eight thread; but the statement of the width would accompany it, and the number of threads per inch in each case would of course be different. In the one case it would be  $66\frac{2}{3}$  splits per inch or  $533\frac{1}{3}$  ends per inch, and in the other it would be 50 splits or 400 ends per inch.

Taking the Yorkshire manufacturing centres, the same diversity exists as in Lancashire. At HUDDERSFIELD the old sett system was based upon the number of beers of 38 ends (19 dents) in 30 inches, but the more rational system of

counting by dents or ends per inch is now universal there. The mode of indicating is generally by stating the dents per inch, and the threads in each dent, as 18 dents 3 threads, which would mean 54 ends per inch. At HOLMFIRTH, a distance of only a few miles from Huddersfield, the sett is based upon 10 ends per foot, so that if there are twenty times ten ends, or assuming two ends in a split, twenty times five splits in one foot: it would be termed a twenty sett. If this were reduced to the same basis as many of the others, *viz.*, the number of beers in a given number of inches it would be equal to the number of beers of 40 ends each in 48 inches.

The DEWSBURY system is based upon the number of beers of 38 ends each in 90 inches or 10 quarters. The BRADFORD system is based upon the number of beers of 40 ends each in 36 inches. Many of the woollen manufacturing districts have their systems based upon the beers, portits, porties, or porters, as they are variously termed, in a given number of inches, but the portits or beers are variable quantities according to the custom of the district, and the number of inches taken as a basis differs also.

The various systems enumerated here are only a few of those in use, as will be readily understood by those engaged in the trade, but they are sufficient to show the general principle upon which most of them are based. One difficulty will be frequently encountered by those who desire to obtain information as to the basis of the systems in use in any district, the majority of those engaged in the trade are not really aware what is the basis of the system upon which they work: they are simply aware that a certain sett means a given number of ends per inch, or some such

simple data, upon which they base all their calculations without really knowing the reasons, and it is only after repeated inquiries and deductions made from the replies received from different parties, that the real basis can be arrived at, but it will be found in the great majority of cases, that the basis is dependent upon the number of beers or porties in a given number of inches.

To convey a little more clearly the difference between the various sett systems, a comparison of a few of them may be made. Take for example, what is spoken of as a 60 sett, and see what number of ends per inch will be contained in some of the systems, it will be as follows:—

		Ends per Inch.	
By ends per inch	...	60 sett represents	60
„ BRADFORD system		60	$66\frac{2}{3}$
„ HUDDERSFIELD (old) do.	60	„	76
„ HOLMFIRTH do.	60	„	50
„ BOLTON do.	60	„	$98\frac{9}{7}$
„ BLACKBURN do.	60	„	$53\frac{1}{3}$

Or to carry the comparison a little further, and permit the introduction of the Scotch and Silk trades, 60 ends per inch would be equal to

BRADFORD...	54	sett.	
BOLTON ...	$36\frac{3}{8}$	„	
BLACKBURN	48	„	
HUDDERSFIELD	$47\frac{7}{19}$	„	
HOLMFIRTH	50	„	
SCOTCH	1110	„	
SILK	720	„	two threads 24 inches

TO FIND THE ENDS PER INCH, OR IN ANY NUMBER OF INCHES, IN ANY SETT SYSTEM.

The next question to determine is the readiest method of finding the number of ends per inch or in any given number of inches of a given

sett, in any of the systems. In the system based upon the number of ends per inch there is of course no difficulty, because the sett multiplied by the number of inches, indicates at once the total number of ends. In those systems based upon the number of beers or porties in a given number of inches, the ends per inch would be found by the following :—

RULE (15).—Multiply the sett by the ends per beer, and divide by the number of inches which is made the basis.

Or to find the ends in any number of inches it would be by the

RULE (16).—Multiply the inches (width of warp in the reed) by sett and by ends per beer, and divide by the number of inches which is made the basis.

It may be said that this latter rule is superfluous, in many cases no doubt it is, but in others it is advantageous, for it saves the trouble of dealing with fractions, and gives accurate results with the least possible amount of labour, considerations which are not to be cast lightly aside. As an illustration of the application of the rules, take the Bradford system, one which is easily applied. To find the ends per inch the sett will require to be multiplied by 40 (the number of ends per beer) and divided by 36 (the inches upon which it is based), then put in the form of an equation it will stand thus :—

$$\frac{\text{Sett} \times 40}{36} = \text{ends per inch.}$$

Or if 40 and 36 are reduced to their lowest terms by cancelling it would be  $\frac{40}{36} = \frac{10}{9}$ , then the

formula  $\frac{\text{Sett} \times 10}{9} = \text{ends per inch.}$

Another method commonly practised to find the ends per inch, is to add one ninth to the sett, because 40 is one ninth more than 36. This is very handy for mental calculations. Now as to the application of the second rule, for finding the number of ends in a given number of inches. Suppose that the number of ends in  $29\frac{1}{2}$  inches of a 56 sett is required, the application of the second rule will give it as follows :—

$$\begin{array}{r}
 29\frac{1}{2} \\
 10 \\
 \hline
 295 \\
 56 \\
 \hline
 9 \overline{)16520} \\
 \underline{1835\frac{5}{9}} \\
 \text{Or } \frac{29\frac{1}{2} \times 56 \times 10}{9} = 1835\frac{5}{9}.
 \end{array}$$

If the ends per inch are found first, it would be for 56 sett,  $62\frac{2}{9}$ , and then to find the total ends required,  $62\frac{2}{9}$  would have to be multiplied by  $29\frac{1}{2}$ , so that the time occupied and the liability to error are much greater. In many cases the fractions may be much more troublesome than in the example given here, so that the advantage will of course be all the greater.

In the Bolton system this formula will be practically the same, merely substituting  $24\frac{1}{4}$  inches for 36, so that the formula would stand thus:

$$\frac{S \times 40}{24\frac{1}{4}} = \text{ends per inch.}$$

Or to find the ends in a given number of inches,

$$\frac{I \times S \times 40}{24\frac{1}{4}} = \text{ends required.}$$

In the Blackburn system again the same formula will apply, substituting 45 inches, thus,

$$\frac{S \times 40}{45} \text{ or } \frac{S \times 8}{9} = \text{ends per inch, and}$$

$$\frac{I \times S \times 8}{9} = \text{ends in inches required.}$$

In the Huddersfield old system the difference would consist in using 38 as a multiplier, and 30 as a divisor, thus,  $\frac{S \times 38}{30} = \text{ends per inch}$ ; and to find the ends in a given number of inches  $\frac{I \times S \times 38}{30} = \text{ends required}$ . But by the system now generally adopted, where the splits per inch and the ends in a split are stated, it will be much readier; thus, say twenty reed, three in a split will be 60 ends per inch, and from this the ends will be readily found for any number of inches.

In the Holmfirth system, the ends per inch may be found by first finding the ends per foot, and then divide by 12, but it is obvious that the process will in most cases be materially shortened by adopting a formula similar to those given.

As the sett when reduced is equal to the number of beers of 40 ends each in 48 inches by the same rule as before, the formula would stand  $\frac{\text{Sett} \times 40}{48} = \text{ends per inch}$ , or reduce  $\frac{40}{48}$  to its lowest terms, thus,  $\frac{40}{48} = \frac{10}{12}$ , and so make the formula  $\frac{S \times 10}{12} = \text{ends per inch}$ , which simply means adding a cypher to the sett, and dividing by 12, the process is at once simplified and

shortened. Or to find the ends in a given number of inches the formula will be  $\frac{I \times S \times 10}{12} = \text{ends required}$ .

Attention may now be turned for a short time to the Scotch and silk trades setts. As has been already shown, the Scotch sett is based upon the number of splits in 37 inches, therefore if the sett be divided by 37, the splits per inch are at once found, and as there are, unless otherwise expressed, two threads in each split, the splits per inch multiplied by 2 gives the ends per inch, thus if it is a 1200 reed, 1200 divided by 37 will give  $32\frac{1}{37}$  splits per inch, or  $64\frac{2}{37}$  ends per inch. If the number of splits or ends in any given number of inches be required, it may be found by simple proportion, thus, as 37 inches : inches given :: sett : reeds in width of piece ; or it may be put as follows:—

$\frac{\text{Sett} \times \text{Inches}}{37} = \text{reeds in number of inches given}$ .

And if the ends are required it will simply be

$\frac{\text{Sett} \times \text{Inches} \times 2}{37} = \text{ends required}$ .

For the silk trade, for the majority of the calculations the ends per inch would not be very frequently required when made upon the basis indicated at page 51, as the total ends in the piece are made to serve the same purpose, but if the ends per inch should be required, they can readily be found. If the piece is a "twelve hundred, eight thread, twenty-four inches," there will be 9600 ends in 24 inches, therefore 9600 divided by 24 will give 400 ends per inch at once, and so on for any sett.

WHEN ENDS, &C., ARE GIVEN TO FIND THE SETT.

One other matter only connected with the question of setts requires to be examined, and that

is simply a reversal of the rules already laid down, *viz.*—when the ends, &c., are given to find the sett. In the rules and examples given, the sett has been given to find ends per inch, or sett and inches have been given to find the total number of ends required.

Where the sett system is based upon ends or splits per inch, this is of course simple enough, but where it is based upon the number of beers in a given number of inches, mistakes are apt to occur, especially with those not much accustomed to calculations. One instance of this may be given; in the Bradford sett system to find the ends per inch in a given sett, it practically amounts to adding to the sett one ninth to find the ends, and this mode of working is regularly practised, and in fact is by many supposed to be the sole basis, thus to find ends per inch in a 54 sett, one ninth of 54 is 6, then  $54 + 6 = 60$ . On the other hand, if the ends per inch are given to find the sett, the common practice of many is to *subtract one ninth*. Now if one ninth has been added to sett to find ends, it becomes *one tenth* of the total, therefore one tenth should be subtracted, thus, taking the 54 sett given, there are 60 ends per inch. Suppose 60 ends per inch are given to find sett, if one ninth were subtracted it would give the sett as  $53\frac{1}{3}$ , because one ninth of 60 is  $6\frac{2}{3}$ , and  $60 - 6\frac{2}{3} = 53\frac{1}{3}$ , but if one tenth be subtracted it will give 54 sett, thus, one tenth of 60 is 6, and  $60 - 6 = 54$ . In other systems similar errors may arise if not guarded against, but this will be always met by the

RULE (17). - Multiply the ends given by the inches upon which the system is based, and divide by ends per beer or portie.



If the total number of ends in the piece are given as well as the inches width, then the sett will be found by the

RULE (18).—Multiply ends by inches upon which the system is based, and divide by ends per beer and inches width of piece.

Or if ends and sett are given to find what number of inches it will stand in the sley, the following will be the

RULE (19).—Multiply ends by inches upon which the system is based and divide by ends per beer and sett.

Each rule may be illustrated by a formula, the figures upon which the Bradford sett is based being used, and the figures of other sett systems may be substituted for them as occasion arises, thus :—

$$\frac{\text{Ends per inch} \times 36}{40} = \text{sett for the first rule, and}$$

$$\frac{\text{Ends} \times 36}{\text{Inches} \times 40} = \text{sett for the second rule, and}$$

$$\frac{\text{Ends} \times 36}{\text{Sett} \times 40} = \text{inches for the third rule.}$$

No matter what may be the basis of the set system these rules and formulæ will apply, it only requires the substitution of the relative values for the figures given here.

## TO CALCULATE WEIGHT AND COST OF WARP.

The whole of the preliminary calculations of counts of yarn and setts already dealt with are part of those required for determining the weight of warp or weft contained in a piece of fabric, and also for determining the cost. Then the next question to deal with is the application of these calculations to the purposes for which they are intended.

It will perhaps be desirable to deal first with the warp, and determine the weight or cost of that, and then in a similar manner with the weft; and to do this in the most satisfactory and complete manner it will be as well to examine the subject from every point of view. Beginning first with the calculation for finding the weight of a warp when the number of ends and the length are known, the subject may be followed step by step through all its various phases. When the system of counts is based upon the hank, the number of hanks contained in a warp may be found by the following:—

RULE (20).—Multiply the number of ends in the warp by the yards in length, and divide by the yards per hank.

Or as a formula  $\frac{\text{Ends} \times \text{yards}}{840} = \text{hanks of}$

cotton contained in the warp. Substitute 560 for 840 and it will give worsted hanks, and so on. If it is required to find the weight of the warp, the number of hanks contained may be divided by the

counts and the weight found at once. This is a very convenient method of dealing with the question when the weight is required to be found in various counts, as is often the case; more especially when it is a question of bringing in a cloth or a warp at a given weight, but if the weight of a warp of a given count is required it is more convenient to put the whole in one formula, thus;

$$\frac{\text{Ends} \times \text{yards}}{840 \times \text{counts}} = \text{weight of the warp in cotton,}$$

and of course substituting 560 if for worsted, or other numbers according to the count system upon which it is based.

So as to make the subject as complete as possible it will be as well perhaps to give the complete formula for other systems of counting besides worsted and cotton, for example, in dealing with woollen on the Yorkshire skein basis, where the yards per dram are equal to the skeins per wartern, or indicating the counts, the number to be used as a constant divisor would be 256, because there are 256 drams per lb., therefore one skein per wartern would be equal to one yard per dram, or to 256 yards per lb.; thus to find the weight of a warp the formula would be

$$\frac{\text{Ends} \times \text{yards}}{256 \times \text{counts}} = \text{weight.}$$

If by the West of England system, where the skein is based upon the number of times 20 yards weigh one ounce, or 320 yards per lb., then substitute 320 for 256, thus:

$$\frac{\text{Ends} \times \text{yards}}{320 \times \text{counts}} = \text{weight.}$$

If dealing with the Scotch systems then it will be necessary to take both the yards and weights into account, as for example, in the Galashiels

system, where the counts is based upon the "cuts" of 300 yards each in 24 ounces, or 384 drams, the readiest method will be to take the formula, thus :

$$\frac{\text{Ends} \times \text{yards} \times 24\text{oz.}}{300 \times 16\text{oz.} \times \text{counts}} = \text{weight of warp.}$$

Or what is equivalent, reduce the ounces to drams, and put the formula thus :

$$\frac{\text{Ends} \times \text{yards} \times 384}{300 \times 256 \times \text{counts}} = \text{weight of warp.}$$

There would be no advantage in the latter, it only shows the relative number of drams, or the terms by which many people know the system, instead of ounces. By the Hawick system it would be

$$\frac{\text{Ends} \times \text{yards} \times 26}{300 \times 16 \times \text{counts}} = \text{weight of warp.}$$

Or given in drams instead of ounces it would be

$$\frac{\text{Ends} \times \text{yards} \times 416}{300 \times 256 \times \text{counts}} = \text{weight of warp.}$$

Other systems might be given, but they would of course be only variations of the above, substituting the relative counts systems for those used, and probably these will be quite sufficient to give a clear indication of the mode of working without unnecessarily multiplying examples.

There should not be much difficulty in understanding the reasons for these formulæ; by multiplying together the number of ends in a warp and the length of the warp, the total length of yarn is at once found; and then dividing that by the number of yards contained in one hank or skein, or whatever is the basis of the system of calculation, the number of hanks, &c., is obtained, and as the counts is determined by the number of

hanks per lb., if the hanks so found be divided by the counts the quotient of course gives the weight.

#### WHEN WEIGHT OF WARP IS GIVEN TO FIND COUNTS.

Sometimes instead of the counts of yarn being given to find the weight of a warp, the weight of the warp is given, and it is required to find what counts of yarn is required to produce that weight. For instance, a manufacturer may desire to produce a cloth in which there is a given weight of warp; he knows the number of ends the warp must contain and he knows what length it should be; then it is required to find the counts of yarn, which will produce exactly what he wants. This would require a simple variation of the preceding rule substituting weight for counts as a divisor, thus:

RULE (21).—Multiply ends by yards and divide by 840 for cotton, or such other number as is the basis of the system for other materials, and by weight the quotient will be the counts sought.

Or as a formula  $\frac{\text{Ends} \times \text{yards}}{840 \times \text{weight}} = \text{counts of cotton.}$

It may be said "Well, this will not frequently be required," but it is, very frequently; and unless the rule be well understood it may lead to the loss of a great deal of valuable time. And, as will be shown later on, it very often becomes a most necessary formula, especially when it is desired to alter the weights of cloths. And apart from that, it is desirable that anyone having to work such calculations should be familiar with every possible phase of the question.

WHEN WEIGHT, COUNTS AND ENDS ARE GIVEN TO FIND LENGTH; OR WHEN WEIGHT, COUNTS AND LENGTH ARE GIVEN TO FIND ENDS.

There are one or two other aspects of this question which must also be considered. Sometimes there is a certain weight of material which must be used up, and it is desired to make a warp which shall use this material with a tolerable certainty that there shall be no small parcel left. One of two conditions may attach to this—first, the weights and counts being known it is desired to make a warp of a given length and the number of ends which such warp will contain is required. Second, the weight and count of the yarn being known it is desired to make a warp containing a given number of ends, and the length of warp containing such number of ends which the material will make is required. The first condition is somewhat analogous to that previously pointed out where a given weight of material is to be employed to produce a cloth, differing from it in respect of both weight and counts being known instead of only weight being known. For the first of these conditions the following will be the

**RULE (22).**—Multiply the weight of yarn by its counts, and by 840 for cotton, and other numbers for other materials as before, and divide by the yards of warp required.

*Example.*—It is desired to make 3lbs. of 40's cotton into a warp 56 yards long, how many ends will it contain?

$$\frac{3 \times 40 \times 840}{56} = 1800 \text{ ends.}$$

or put in a general formula it will be

$$\frac{\text{Weight} \times \text{counts} \times 840}{\text{yards}} = \text{ends which the}$$

warp will contain.

If the material is worsted, substitute 560 for 840; if woollen (Yorksire skein) 256, and other numbers for other systems.

In the second case, where the ends are given, and it is required to find the yards, substitute ends for yards in the formula, thus:

$$\frac{\text{Weight} \times \text{counts} \times 840}{\text{ends}} = \text{yards.}$$

Or stated as a

RULE (23).—Multiply weight by counts and by 840 (for cotton), and divide by ends, the quotient will be yards.

*Example.*—It is required to make 3lbs. of 40's cotton into a warp containing 1800 ends, how many yards will the warp be?

$$\frac{3 \times 40 \times 840}{1800} = 56 \text{ yards.}$$

The explanation of these rules is simply that weight multiplied by counts gives the number of hanks of yarn to be used, and that multiplied by the number of yards in each hank, gives the total number of yards of yarn, which divided by the number of ends will necessarily give the length of each end, and consequently the length of the warp. Or on the other hand, if divided by the length of the warp it will give the number of ends, each of the length so stated.

#### WARP AND SETT CALCULATIONS COMBINED.

These formulæ for the warp may now be combined with those given for the sett calculations,

and so in many cases materially shorten the calculations necessary, and even if there is no actual shortening, it is better to state a question as a whole than to deal with it in sections, because the statement will show everything on the face of it, and there is consequently less liability to error.

Suppose the weight and counts of the material to be used is given, and the length of warp and the width in the sley are also given, and it is required to find the sett in which to weave it, if the sett system is based upon the number of ends per inch, it would simply be adding to the divisors given in a previous rule the number of inches the warp must occupy in the reed so as to find the number of ends per inch, thus, in the example given at page 64; if the warp must occupy 30 inches in the reed it would be

$$\frac{3 \times 40 \times 840}{56 \times 30} = 60 \text{ ends per inch.}$$

If the sett system be based upon the number of beers or portits contained in a given number of inches, then the ends per beer or portit will become one of the numbers forming the divisors, and the inches will become one of the numbers forming the dividend. Thus in the Bradford sett systems, when the number of beers of 40 ends in 36 inches forms the basis it would be

$$\frac{\text{Weight} \times \text{counts} \times 840 \times 36}{\text{Inches} \times \text{yards} \times 40} = \text{sett.}$$

And for the example given above to find the sett

$$\frac{3 \times 40 \times 840 \times 36}{56 \times 30 \times 40} = 54, \text{ the sett required.}$$

For any other sett system it would be a question of substituting the ends per beer or portit, and the number of inches employed, and the result will be



the same. For instance, in the Lancashire system when the basis is the number of beers of 40 ends each in  $24\frac{1}{4}$  inches, the latter number would be substituted for 36 in the calculations just given.

To ascertain the cost of a warp there is little to do after the weight is found, the price per lb. being known, the weight multiplied by that price of course gives the total cost.

TO FIND COUNTS, WEIGHT, &c., OF A WARP IN ONE MATERIAL EQUAL TO A GIVEN WARP IN ANOTHER MATERIAL, OR WHEN THE WEIGHT IS TO BE ALTERED.

It sometimes occurs that a warp is required in one material of the same weight, or bearing a certain relation as regards weight to a given warp in another material. In such cases the question is simply one of proportion in which the counts basis become factors, as well as the relative weights of the two warps, but in the simplest manner. Suppose it is required to find the counts of yarn which will produce in cotton a warp equal to 48's worsted. Here the question is simply one of relative counts, exactly similar to those given at page 18, and would be stated thus,  $\frac{48 \times 2}{3} = 32$ 's the counts of cotton required; the explanation being simply that 32's cotton is equal to 48's worsted, or in other words, that 32 hanks of 840 yards each are equal to 48 hanks of 560 yards each.

If further, the warp is required to be altered in weight, made heavier or lighter, then the counts will necessarily require to be higher or lower accordingly, for example, if the warp is to be one-third heavier, then the counts will require to be lower in the proportion of 4 to 3, because the warp

being one-third heavier, the three parts of which it originally consisted must be increased to four, thus it will be  $\frac{3^2 \times 3}{4} = 24$ 's the counts required to obtain the increased weight, or to put the whole question in one formula, which is unquestionably the best, it will be  $\frac{48 \times 2 \times 3}{3 \times 4} = 24$ 's the counts required. If the warp should require to be, say, one-third lighter, then the counts will require to be higher in the proportion of 2 to 3, because being one-third lighter, the three parts of which it originally consisted would be reduced to two, therefore the formula would be  $\frac{48 \times 2 \times 3}{3 \times 2} = 48$ 's. In this case the alteration in weight has exactly counteracted the number of yards per hank in the two materials.

No matter what may be the relative weight of two warps the required counts may be easily found, only bear carefully in mind that a heavier warp will mean lower counts, and a lighter warp higher counts. Suppose for a further example the warp is required to be one fifth lighter, the formula would be  $\frac{48 \times 2 \times 5}{3 \times 4} = 40$ 's, the counts of warp required (changing from worsted to cotton as before). Or if it should be required one-fifth heavier it would be  $\frac{48 \times 2 \times 5}{3 \times 6} = 26\frac{2}{3}$ 's the counts required.

In dealing with any two materials the rules will be precisely the same, substituting the number of yards per hank, skein, &c., for the numbers used here

The system of proportion may be carried to a considerably greater length than it has been done here. The examples already shown, although sufficiently valuable in themselves, are only a few of the simplest applications of the principle, but such as may be required in every day work, and consequently what everyone engaged in the manufacturing industries should be thoroughly familiar with. The application of the principle may now be considered when two materials are employed as warp in the same cloth, thus,

TO FIND THE COUNTS OF ONE MATERIAL USED AS WARP ALONG WITH ANOTHER MATERIAL—AS WOOLLEN WITH WORSTED—THE COUNTS OF THE SECOND MATERIAL, AND THE RELATIVE WEIGHT OF EACH BEING KNOWN.

This will apply more especially to double cloths, whether all woollen, worsted and woollen, or the combination of any two materials. It is very often required, for instance, to produce a worsted coating cloth with a woollen back upon it, the cloth must weigh a given number of ounces per yard, and the cost not to exceed a certain sum; this will admit of a certain quantity of worsted at a given price, and a certain quantity of woollen at a much lower price; the counts of the material which is to form the face cloth is known, and it is required to find the counts of woollen for the back, which along with the face yarn will produce the weight required—the relative number of ends of each being given.—This will be determined by the

RULE (24).—Reduce the counts of the given material to the denomination of the required material, then, as the ends of one warp is

to the ends of the other warp required, so is the counts given to the counts required, if the weight of each is equal.

*Example.*—It is required to make a cloth with 2/40's or equal to 20's worsted warp for face, and a woollen back upon it, the weight of face and back to be equal, and to have two ends of worsted to one of woollen, what will the counts of woollen require to be in Yorkshire skein system.

To find the counts of woollen equal to the 20's worsted by rule at page 67 :

$$\frac{20 \times 560}{256} = 43\frac{3}{4}.$$

and as there are two ends of worsted to one of woollen, as  $2:1::43\frac{3}{4}:21\frac{7}{8}$ , the counts of woollen required. If the counts of woollen be given and it is required to find the counts of worsted, it would be simply reversed, thus:

$$\frac{21\frac{7}{8} \times 256}{560} = 10\text{'s worsted.}$$

then as  $1:2::10:20$ , the counts of worsted sought.

It is however much more convenient, and will not only conduce to a saving of time, but also to accuracy, to treat the whole question in one formula, in the first instance

$$\frac{20 \times 560 \times 1}{256 \times 2} = 21\frac{7}{8}.$$

and in the second,

$$\frac{21\frac{7}{8} \times 256 \times 2}{560 \times 1} = 20,$$

or in other words, treat the question as one of compound proportion.

Before proceeding further it will be well perhaps, to prove the truth of this rule by one example which will illustrate its accuracy. Suppose the weight of two warps of similar lengths, and of the counts dealt with in the foregoing example, be found. Let the warps contain 2000 and 1000 ends respectively, and both be 50 yards long, what is the weight of each? by rule 20

$$\frac{2000 \times 50}{560 \times 20} = 8\text{lbs. } 15\text{oz. nearly,}$$

as the weight of the worsted warp, and

$$\frac{1000 \times 50}{256 \times 21\frac{7}{8}} = 8\text{lbs. } 15\text{oz. nearly,}$$

as the weight of the woollen warp, thus proving the truth of the rule.

If the weight of face and back are not equal, as often happens, then their relative weights must be taken into account in the calculation, which would simply mean that after the counts have been found for equal weights, the counts for the altered weight will be found by

RULE (25).—As the weight of one warp is to the weight of the other warp, so will the counts found for equal weight be to the counts required for unequal weight.

Thus, if in the previous case the weight of the two warps respectively had been 3 of face to 5 of back, then, as  $5:3::21\frac{7}{8}:13\frac{1}{8}$ , the counts required.

To prove that this is true, take again the warp of 1000 ends and 50 yards and find its weight with the counts at  $13\frac{1}{8}$ 's, thus:

$$\frac{1000 \times 50}{256 \times 13\frac{1}{8}} = 14\text{lb. } 14\text{oz. — a little over.}$$

And 8lb. 15oz. the weight of the face warp is to 14lb. 14oz., as 3 is to 5, thus proving the accuracy of the rule.

This, like all the others will be most readily dealt with by arranging it all in one formula, thus:

$$\frac{20 \times 560 \times 1 \times 3}{256 \times 2 \times 5} = 13\frac{1}{8}.$$

Or to put it in general terms, let A be the counts, B the yards per hank of one material, C the proportion of ends, and D the relative weight of the given warp, E the yards per hank of the second material, F the proportion of ends of the second material, and G the relative weight of the required warps; thus the formula will be

$$\frac{A \times B \times F \times D}{E \times C \times G} = \text{counts sought.}$$

This rule is easy of application, and will be found to be correct under any conditions.

WHEN TWO MATERIALS OR COUNTS ARE TO BE USED, THE PROPORTION OF THREADS OF ONE TO THE OTHER BEING KNOWN, TO FIND THE ENDS PER INCH TO PRODUCE A WARP OF GIVEN WEIGHT.

The application of the rules of proportion to the calculations of warps, which next claims attention is when a double cloth is to be made, or for any purpose two different materials, or two setts of threads of the same material but different counts are to be employed, the proportion of threads of one to the other being known, and it is required to determine the number of threads of each per inch, or in any given space, to produce a warp of a given weight. The simplest plan will be to treat the question first on the basis of finding the ends

per inch, and then to show its application to any sett system. And further, to treat it first with the two sets of threads of the same material, or calculated on the same basis, then to deal with two different materials, or materials calculated on different bases. There are two or three methods of working out this kind of question ; consequently each one will be taken in succession so as to make the matter as clear and complete as possible. First proceed upon the assumption that the threads which form the face and back respectively, as two threads of face and one of back yarn equal one thread, as for the purposes of this calculation they do practically form one thread, then by Rule 2 find the counts resulting from this combination, then by the

RULE (26).—As the counts of one yarn divided by the proportion it represents of the total number of ends is to the resulting counts, so is the total weight to be produced to the weight required of that yarn. Then having found the weight of each yarn to be employed, find by Rule 22 the number of ends per inch, or sett, which will give that weight.

*Example.*—Suppose a cloth is to be made, the warp of which shall weigh 40lbs., the face cloth to be 30 skein woollen, and the back to be 10 skein, both Yorkshire counts, there are to be two threads of face to one of back, the width of the piece to be 64 inches in the reed, and the length of warp 50 yards; how many ends of face and back respectively per inch will be required ?

First by Rule 13, two threads of 30's and one of 10's together will be equal to

$$30 \div 30 = 1$$

$$30 \div 30 = 1$$

$$30 \div 10 = 3$$


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$30 \div 5 = 6$ 's, the resulting count.

And next to find the weight of each material required to make up the 40lbs:

As  $\frac{30}{2} : 6 :: 40 : 16$ lbs., the weight of face yarn

required, and as  $\frac{10}{1} : 6 :: 40 : 24$ , the weight of back yarn required, and  $24 + 16 = 40$ . Next to find the

ends of each respectively, 16lbs. of 30's woollen will give  $\frac{16 \times 30 \times 256}{64 \times 50} = 38.4$  ends of face, and for

the back  $\frac{24 \times 10 \times 256}{64 \times 50} = 19.2$  ends.

Suppose it is desired to have three ends of the fine yarn to one of the heavy, and the total weight of warp is to be 35lbs., using the same two counts as before, and the same width and length of warp, then to find the counts resulting from the putting together of three fine and one heavy threads, it would be

$$30 \div 30 = 1$$

$$30 \div 30 = 1$$

$$30 \div 30 = 1$$

$$30 \div 10 = 3$$


---

$30 \div 6 = 5$ , the counts of the resulting thread; and to find the weight of each,

$\frac{30}{3} : 5 :: 35 : 17\frac{1}{2}$ lbs., the weight of face warp, and

$\frac{10}{1} : 5 :: 35 : 17\frac{1}{2}$ lbs., the weight of back, so that the



weight of face and back are equal. It is evident that this must be the case from the fact, that there are three threads of 30's, or equal to one of 10's when put together, and these coming against one of 10's, the two must necessarily be equal. Next to find the ends per inch of each it will be

$$\frac{17\frac{1}{2} \times 30 \times 256}{64 \times 50} = 42 \text{ ends of face warp, and}$$

$$\frac{17\frac{1}{2} \times 10 \times 256}{64 \times 50} = 14 \text{ ends of back warp.}$$

This will be sufficient to illustrate this particular mode of working. Of course, no matter what the material used may be, the question being simply one of proportion, the working will be exactly the same.

The mode of working just dealt with is given at length for the purpose of demonstrating clearly the principle which underlies this kind of calculation, but it may now be dealt with in a much more simple and easy manner, and consequently with less liability to error. Instead of finding the counts which would result from the placing together of the three or four threads which represent the relative proportions of the two sets of threads, these need only to be taken into consideration in conjunction with the relative counts of the two yarns. For instance the two yarns given in the two examples are respectively 30's and 10's woollen. It might equally have been worsted, cotton, or any other material. Now if one thread of each must be employed alternately the quantity or weight of each yarn would have been inversely as 3 to 1, because 1lb. of 30's would contain as many yards as 3lbs. of 10's, consequently if 40lbs. must be employed in the total there would have been 30lbs. of 10's and 10lbs. of 30's. But the threads are to be arranged with two of the 30's to

one of the 10's, therefore there must be an increase in the quantity of 30's and a corresponding decrease in the quantity of 10's, and that alteration in quantity will be represented by the formula  $\frac{30 \times 1}{10 \times 2} = \frac{30}{20}$  so that they will now stand to each other as 3 to 2. Or there will be three-fifths of the total weight required of 10's and two-fifths of 30's instead of three-fourths and one-fourth respectively. From this will be deduced the

**RULE (27).**—As the first count multiplied by the proportionate number of ends of the second count is to the second count multiplied by the proportionate number of ends of the first count, so is the required weight of yarn of one count to the required weight of yarn of the other count, inversely.

Then as the total weight of yarn is given, usually, which must be employed the weight of each respectively may be found by the

**RULE (28).**—As the sum of the two terms of the proportion already found is to each of those terms, so is the total weight of yarn to be employed, to the weight of each inversely.

Take for example the case of 3 threads of 30's to one of 10's yarn, and to find the weight of each required to make 35lbs. in the total, it would stand thus:  $\frac{30 \times 1}{10 \times 3} = \frac{30}{30}$ , or as 1 to 1; then as the two terms are equal, the warp would be divided in equal portions, or  $17\frac{1}{2}$  lbs. of each.

Or take another

*Example.*—It is required to make a warp weighing 48lbs., there must be two threads of 24's yarn to one of 9's yarn; what weight of each will be required?

$$\frac{24 \times 1}{9 \times 2} = \frac{24}{18} = \frac{4}{3}, \text{ and } 4 + 3 = 7.$$

Then as 7:4::48:27 $\frac{3}{7}$ lbs.

And as 7:3::48:20 $\frac{4}{7}$ lbs. and  $27\frac{3}{7} + 20\frac{4}{7} = 48$ , therefore those are the weights of each yarn required respectively, that is 20 $\frac{4}{7}$ lbs. of 24's yarn and 27 $\frac{3}{7}$ lbs. of 9's yarn. Having found the weight of each, find the ends by Rule 22.

WHEN TWO MATERIALS ARE EMPLOYED, EACH OF KNOWN COUNTS, AND THE WEIGHT OF THE WARP IS KNOWN.

It will be necessary now to follow up this branch of the subject, and deal with the calculations for warps, where two different materials are employed each of known counts, and the total weight of the warp is also known. Questions of this kind may be dealt with in exactly the same manner as those already given, by first reducing both materials to the same value or denomination. For instance suppose the two materials are worsted and cotton, the worsted may be reduced to the cotton standard, or the cotton to the worsted standard, then proceed as by rule 3, to find what would be the resulting counts of any number of threads of worsted with one of cotton, or *vice versa*, and proceed to work the calculation on that basis. Suppose the worsted is 12's, or equal to 2/24's, and the cotton is 1/20's, or equal to 2/40's, if reduced to the same denomination the 12's worsted would be equal to 8's cotton, or the 20's cotton to

30's worsted, and if there are two threads of worsted to one of cotton, the counts resulting from such a combination would be equal to 5's worsted, or to  $3\frac{1}{3}$ 's cotton, thus,

$$20 \div 20 = 1$$

$$20 \div 8 = 2\frac{1}{2}$$

$$20 \div 8 = 2\frac{1}{2}$$

---


$$20 \div 6 = 3\frac{1}{3}'\text{s in cotton counts.}$$

Or  $30 \div 30 = 1$

$$30 \div 12 = 2\frac{1}{2}$$

$$30 \div 12 = 2\frac{1}{2}$$

---


$$30 \div 6 = 5'\text{s in worsted counts.}$$

For the calculation to determine the number of threads per inch of each it is quite immaterial which basis is used as they both necessarily give exactly the same result. Suppose the total weight of yarn to be employed is 30lbs., it is now desired to find the weight of each yarn respectively by the rule 28 given at page 76.

As  $\frac{20}{1} : 3\frac{1}{3} :: 30\text{lbs.} : 5\text{lbs.}$ , the weight of cotton, and

As  $\frac{8}{2} : 3\frac{1}{3} :: 30\text{lbs.} : 25\text{lbs.}$ , the weight of worsted.

Or as  $\frac{30}{1} : 5 :: 30\text{lbs.} : 5\text{lbs.}$ , of cotton, and

As  $\frac{12}{2} : 5 :: 30\text{lbs.} : 25\text{lbs.}$  of worsted.

Thus proving that it makes no difference to which denomination or system of counting the two are reduced.

In this, as in the previous case, the method of working shown is the longest, and a ready proportion may be found which will enable the

work to be done much more quickly, and with much less complication. In the first place, the two yarns, although counted on different systems, necessarily bear a certain proportion to each other in the yards per lb. And this proportion can be readily found, thus the 20's cotton contains  $20 \times 840$  yards per lb. And the 12's worsted contains  $12 \times 560$  yards per lb. Then instead of going through the formality of reducing them to the same value or counts of the same system, simply use them as they are, and apply the Rules 27 and 28, thus:

$\frac{20 \times 840 \times 2}{12 \times 560 \times 1} = \frac{5}{1}$  And as the total weight is 30lbs.  
 As 6:1::30:5lbs., the weight of cotton, and  
 As 6:5::30:25lbs., the weight of worsted.

Take another illustration. It is desired to make a cloth with worsted and woollen warps, there being two threads of worsted to one of woollen, the total weight to be 45lbs., the counts of worsted to be 2/28's, or equal to 14's, and the woollen to be 12 skein (Yorkshire counts), what weight of each will be required?

$$\frac{14 \times 560 \times 1}{12 \times 256 \times 2} = \frac{245}{192}, \text{ and } 245 + 192 = 437.$$

Then as 437:245::45lbs.: 25.23lbs. of woollen.

And as 437:192::45lbs.: 19.77lbs. of worsted.

And  $25.23 + 19.77 = 45$ lbs., the total weight required.

Having found the weight of each material to be used, it is of course easy by rule 22 to find the number of ends per inch for any length or width of piece required.

Whatever the two materials to be used may be, the rule will always apply, and there can be no doubt as to the accuracy of the results.

WHEN TWO MATERIALS—AS WOOLLEN AND WORSTED—ARE TO BE USED IN A CLOTH, THE TOTAL WEIGHT, THE PROPORTION OF EACH, AND THE ENDS PER INCH BEING KNOWN, TO FIND THE COUNTS OF EACH.

This is merely a variation of the rule given at page 59, where width and length of piece, ends per inch, and weight of material are given to find counts, the only difference being, that the weight of two warps are given together instead of each being given separately, this may be worked in two ways, first, find what will be the actual weight of each warp, then deal with it according to rule 21, or second, use the total weight along with the fractional part which is to represent each warp, so as to put the whole question in one equation.

*Example.*—The warp for a cloth must weigh 36lbs., and be composed of two threads of worsted to one of woollen, the relative weights of the two yarns must be  $\frac{3}{7}$  of the total weight to be worsted, and  $\frac{4}{7}$  woollen. The cloth to have 60 ends per inch of worsted and 30 per inch of woollen for 64 inches, and 48 yards long.

By the first process,  $\frac{3}{7}$  of 36lbs. =  $15\frac{3}{7}$ lbs. and  $\frac{4}{7}$  of 36lbs. =  $20\frac{4}{7}$ lbs.

Then  $\frac{60 \times 64 \times 48}{560 \times 15\frac{3}{7}} = 10\frac{2}{3}$ , the counts of worsted.

And  $\frac{30 \times 64 \times 48}{256 \times 20\frac{4}{7}} = 17\frac{1}{2}$ , the counts of woollen.

Or by the second process, which comes to exactly the same thing.

$\frac{60 \times 64 \times 48}{36 \times \frac{3}{7} \times 560} = 10\frac{2}{3}$ , the counts of worsted.

And  $\frac{30 \times 64 \times 48}{256 \times 36 \times \frac{4}{7}} = 17\frac{1}{2}$ , the counts of woollen.

These two must necessarily be the same, because 36 multiplied by  $\frac{3}{7}$  lbs. must be equal to  $15\frac{3}{7}$ , and 36 multiplied by  $\frac{4}{7}$  lbs. is equal to  $20\frac{4}{7}$  lbs.

Instead of the ends being given to find counts, the counts may be given and ends required to be found, in which case it will simply be a variation of rule 21, the proportionate weight being used. In fact the working may be turned in every variety of form, but it always resolves itself into using a certain proportion of the total weight for each warp, and then dealing with it according to rules already given.

#### SHORT METHODS OF CALCULATING WARPS.

Sometimes short methods of calculating are adopted, which considerably facilitate the work, but these must be arranged, generally, to suit the peculiarities of some particular trade or branch of trade. They are often dependent upon the warp being of a given length, or some special length is taken as the unit of measurement. Consequently each individual may make short methods for himself, which will answer all his purposes under certain conditions, but he must be aware that they will only serve under those special conditions and will not be of general application. One example may be given here which will serve to illustrate the principle upon which these short methods may be arranged. In some districts of Yorkshire the sett is reckoned by the portit or portie of 38 ends, the counts of the yarn by what is known as the Yorkshire skein system; which, as already shown, is based upon the number of yards per skein being equal to the drams per wartern, that is the skein is 1,536 yards, and the warp is measured in length by "strings" of 10 feet each, and the wartern 6lbs. or 1,536 drams. Then for finding

the weight of a warp, the number of porties in the warp is divided by the counts, and the quotient is the weight in warterns of 12 strings of warp, thus: if a warp contains 80 porties of 38 ends each, and is 20 skein yarn,  $80 \div 20 = 4$  warterns or 24lbs. weight for 10 strings. This system is very handy in the district where it is used, as the sett is always spoken of as so many porties, and the length as so many strings. And also the weight by the wartern, but outside that particular district it would be most intricate and difficult to apply.

The explanation of the abbreviation is simply this, 38 ends equal one portie, and 10 feet one string, therefore one portie of one string length is equal to 380 feet, and for 12 strings 4,560 feet, or 1,520 yards. 1,536 yards in one skein, thus leaving a margin between 1,520 and 1,536 of 16 yards for shrinkage, &c., in the yarn, and leaving this margin, one portie of 12 strings length of 1 skein yarn, will weigh one wartern, and consequently whatever number of skeins weigh one wartern, divide the number of porties by that count, and the answer must be the weight in warterns.

Other abbreviated methods might be given, but they, like this, are applicable to some particular district or trade, and the ingenious will have no difficulty in making short methods for themselves.



## TO CALCULATE WEIGHT, COST, &c., OF WEFT.

The calculations required for wefts, are, in many respects, very similar to those for warps. And a large proportion of the rules given for warps will be equally applicable to wefts. The mode of finding the quantities in the first instance differs to a slight extent, but all the questions dealing with proportionate quantities; counts, weights, &c., are practically the same. The first requisite in beginning to deal with the calculations of weft is

TO FIND THE LENGTH, HANKS, OR WEIGHT OF  
YARN CONTAINED IN A GIVEN LENGTH OF CLOTH,  
THE WIDTH OF THE CLOTH AND THE PICKS, OR  
THREADS PER INCH BEING KNOWN.

¶ What is meant by this is that a piece of fabric is to be produced of a given width, and with a given number of weft threads per inch, and it is required to find what length of yarn will be required to produce a given length of cloth. This length may be one yard or any number of yards. Suppose in the first place one yard of cloth be taken, then from that the length for any number of yards can be easily found, thus the following would be the

RULE (29).—Multiply the width of the piece by the picks per inch, and the product will be equal to the inches of yarn contained in one inch of cloth, and consequently to the yards of yarn in one yard of cloth.

*Example.*—A cloth of 30 inches wide has 60 picks per inch; what length of yarn does one yard of cloth contain.

30 inches  $\times$  60 picks = 1,800 inches of yarn contained in one inch of cloth, therefore there are 1,800 yards of yarn in one yard of cloth.

The reason of course is obvious, the inches per yard of cloth are equal to the inches per yard of yarn, therefore the length in inches of yarn in one inch of cloth is equal to the length in yards of yarn of one yard of cloth.

Then to follow this up and find the length of yarn in a given length of cloth, it is only necessary to multiply the length of yarn found in one yard of cloth by the length of cloth, and the product will be the total length of yarn.

*Example.*—If for the above cloth it is required to find the length of yarn in 50 yards of cloth, then  $1800 \times 50 = 90,000$  yards, the length of yarn in 50 yards of cloth.

Having thus found the total length of yarn, it is easy to reduce it to hanks, skeins, or, if desired to find the weight. For instance, knowing that the piece contains 90,000 yards of yarn, if that number be divided by 560, it will give at once the number of worsted hanks thus,  $90,000 \div 560 = 160\frac{5}{7}$  hanks of worsted.

If for cotton, thus,  $90,000 \div 840 = 107\frac{1}{7}$  hanks of cotton, and similarly for any other material. Then having found the number of hanks, or skeins, if it is desired to find the weight, this need only be divided by the counts, thus, if the above was 20's worsted, or cotton,  $160\frac{5}{7} \div 20 = 8\frac{1}{8}$  lbs., and  $107\frac{1}{7} \div 20 = 5\frac{5}{14}$  lbs., the weight of each respectively. Then without giving separate rules for each working, as each would be simply an extension of the other, they may be most readily given as formulæ. Let I be inches, the width of the piece

P, picks per inch, Y, yards, the length of the piece, and C, the counts of the yarn, and N, the number of yards per hank, skein, or whatever may be the basis of the counts, thus,

$$\frac{I \times P \times Y}{N} = \text{hanks, \&c,} \quad \text{and} \quad \frac{I \times P \times Y}{N \times C} = \text{weight.}$$

In these formulæ no allowance is made for shrinkage or waste of yarn in the process of weaving; the reason for this will be obvious to anyone having a knowledge of the subject; the difference in the shrinking properties of different yarns, the amount of waste made in weaving different yarns, and probably more than all the influence of pattern, relative number of ends and picks per inch, and structural considerations generally, upon the amount of shrinkage which will take place in a cloth, are such as to render it impossible to lay down any fixed rule as to what allowance should be made; this can only be determined by careful observation and an intimate acquaintance with the material, the structure of cloths, and generally the conditions which will affect it. The best rule is to make the calculations on the basis of the actual width of the cloth, or the width in the reed, and the actual length of cloth, then add such a percentage for shrinkage, waste, &c., as experience has taught to be sufficient, by this means more accurate results will be obtained than by any attempt to work by a fixed rule. Of course all that has been said with respect to the application of the different count systems in calculating warps applies equally to the weft. All the formulæ given at pages 56 to 78 will serve equally for weft by merely substituting picks and inches for ends. Yards, counts, ends per hank or skein, and all the data remain exactly the same for weft as for warp, the sole difference is in the fact that for the warp a series of threads

running the entire length of the piece are dealt with, and by multiplying the length of the warp by the total number of ends in it, the total length of yarn is obtained, and for weft, where the threads run across the piece, it is more convenient to deal with the number per inch, as the total number of threads of weft in a long piece, or even in a yard of cloth, are not so readily determined, or so conveniently spoken of, as the number per inch.

It will be, perhaps, desirable to give briefly the application to wefts of the rules which have been already laid down for warps, so as to make the subject as clear and complete as possible.

It very frequently happens that a cloth must be produced in which a fixed quantity of weft must be used, either a given number of hanks, or a given weight of known counts, and it is required to find what number of picks per inch must be employed. Or it may be that the picks per inch is already determined, and the counts is required which will produce a certain weight; or the weight, counts, and picks being known, it is required to know what length of piece of a given width, or what width of a given length can be produced. These latter propositions will in most cases arise in connection with the using up of small parcels of yarns, where it is required to make a cloth just sufficient to use up a certain parcel. Then taking these in their order the first will be

TO FIND THE PICKS PER INCH IN A CLOTH TO USE A CERTAIN QUANTITY OF WEFT, THE WIDTH AND LENGTH OF PIECE BEING KNOWN.

RULE (30).—If the quantity is given in hanks, multiply the hanks by the yards per hank, and divide by the length and width of piece.

Or, if weight and counts are given, multiply weight, counts, and yards per hank together and divide by length and width of piece.

*Example 1.*—A piece must contain 180 hanks of worsted, the length of the piece to be 48 yards, and width 28 inches; what number of picks must it contain?

Stated as a general formula it will be

$$\frac{\text{Hanks} \times \text{yards per hank}}{\text{Yards} \times \text{inches}} = \text{picks per inch.}$$

Then  $\frac{180 \times 560}{48 \times 28} = 75$  picks per inch, or

*Example 2.*—A piece must contain 40lbs. of 20's woollen (Yorkshire skein), the length to be 56 yards, and width 64 inches; what number of picks per inch will be required.

$$\frac{40 \times 20 \times 256}{64 \times 56} = 57\frac{1}{7} \text{ picks per inch; and}$$

similarly for any other material, weight or counts.

The reasons for these rules will be sufficiently apparent after those for the warps have been mastered, multiplying the quantity given, whether it be in hanks, or weight and counts, by the number of yards per hank, will give the total number of yards to be used, then dividing by the length of the piece in yards, the length of yarn in one yard of cloth is obtained, and that divided by the width of piece must necessarily give the number of picks or threads per inch. Then next

TO FIND THE WIDTH OR LENGTH OF A PIECE WHICH WILL CONTAIN A GIVEN QUANTITY OF WEFT, THE PICKS PER INCH BEING KNOWN.

RULE (31).—If width is given, multiply the quantity in hanks—or weight by counts—by yards per hank, and divide by picks per inch, and by width in inches.

Or if length is given, substitute length for width as a divisor.

*Example 1.*—A piece having 64 picks per inch must contain 112 hanks of cotton, the width to be 36 inches; what length of piece will it make?

The general formula is

$$\frac{\text{Hanks} \times \text{yards per hank}}{\text{Inches} \times \text{picks}} = \text{yards length, or}$$

$$\frac{\text{Hanks} \times \text{yards per hank}}{\text{Yards} \times \text{picks}} = \text{inches width;}$$

or if weight and counts are given, substitute them for hanks; then

$$\frac{112 \times 840}{36 \times 64} = 40\frac{5}{8} \text{ yards, the length of the piece.}$$

*Example 2.*—A piece must contain 48lbs. of 16 skein woollen (Yorkshire count), the number of picks to be 48 per inch, and the length 60 yards; what width must it be?

$$\frac{48 \times 16 \times 256}{48 \times 60} = 68\frac{4}{15} \text{ inches, width of piece.}$$

In this, as in the other subjects, it would be an easy matter to multiply the examples indefinitely and apparently vary the mode of working, but it would simply be dealing with the different systems of counting, and presuming that those are well understood and that one system is properly substituted for another in the working of the calculations, it would be a waste of time to trouble the reader with further examples.

The question of cost of weft, as of warp, can be easily found; having ascertained the quantity contained in a piece, multiply by the price per lb. and the total cost is at once found.

TO FIND THE COUNTS, WEIGHT, &c., OF WEFT IN ONE MATERIAL EQUAL TO GIVEN WEFT IN ANOTHER MATERIAL, OR WHEN THE WEIGHT IS TO BE ALTERED.

This is precisely the same as that given for warps at page 63, being simply questions of proportion, in which the basis of the counts system must be taken into account, and as the subject has been so fully treated already in connection with warps, it is not necessary, respecting its application to weft, to say more than that all the conditions are precisely similar, the counts, weight, &c., being found in exactly the same manner, and having found those, apply the rules and formulæ given here for wefts in place of those previously given for warps. In the same manner,

WHEN TWO MATERIALS ARE TO BE EMPLOYED, OR TWO SETS OF THREADS OF THE SAME MATERIAL BUT DIFFERENT COUNTS, THE PROPORTION OF PICKS OF ONE TO THE OTHER BEING KNOWN, AND IT IS REQUIRED TO DETERMINE THE NUMBER OF PICKS OF EACH PER INCH TO PRODUCE A CLOTH OF A GIVEN WEIGHT.

The rule given at page 68 will apply, the only difference being for sett reed picks, and vary the formula accordingly, and the abbreviation given at page 71 of the rule above mentioned will of course apply equally. It may in fact be said at once, that everything which applies to warp calculations applies equally to weft calculations, substituting picks for ends per inch or sett, and using such formulæ as are given for weft instead

of those given for warp. Before leaving this branch of the subject, a few examples may be given in which both warp and weft will be dealt with, so as to show more completely the application of the rules. This will perhaps assist in making it clearer and preventing any misconception of their application.

#### PRACTICAL APPLICATION OF THE PRECEDING RULES.

The illustrations of the application of the rules already laid down will be as few and brief as possible, consistently with a complete knowledge of them, and how they may be dealt with. It will scarcely be necessary to deal with the rules applied to counts of yarn and setts, as they are sufficiently illustrated in the examples which accompany the rules themselves, but those referring to warps and wefts will probably leave room for a little more examination, and they may be combined, so as to work out the calculations for complete fabrics in all the various forms. These examples will be taken in the order in which the rules are already given, beginning at rule 20.

*Example 1.*—What is the cost of a cloth made from  $2/60$ 's cotton warp, and  $36$ 's worsted weft, 72 ends per inch, 80 picks of weft per inch, to be 32 inches wide in the reed, length of piece to be 48 yards, made from 54 yards of warp, price of cotton to be  $2/4$  per lb., and worsted  $3/4$  per lb., allow 5 per cent. of weft for actual waste?

The working of the question will be as follows, by rule 20, for the warp  $\frac{72 \times 32 \times 54}{840 \times 30} = 4\text{lb. } 14\frac{4}{5}\frac{2}{5}$  or 4lbs. 15oz. weight.

This weight at  $2/4$  per lb. will be equal to 11s.  $6\frac{1}{4}$ d. as the cost of warp.



Instead of finding the weight the cost may be readily found at once, though it is often convenient, if not necessary, to know the weight; then to find the cost direct simply use the price per lb. as one of the enumerators, thus:

$$\frac{72 \times 32 \times 54 \times 28}{840 \times 30} = 138\frac{126}{525} \text{ pence, or}$$

equal to 11s. 6¼d. (the price is here used in pence, but of course it may be used either as pence or otherwise).

For the weft the following is the working by rule 29,

$$\frac{80 \times 32 \times 48}{560 \times 36} = 6 \text{ lbs. } 1\frac{1}{2} \text{ ozs., and}$$

6lbs. 1½ozs. at 3/4 equals 20s. 3¼d. as the cost of weft. To this must be added the 5 per cent. for actual waste, making the total cost 21s. 4d.

Sometimes in making calculations for weft, the number of hanks are found, and the allowance for waste added there, before finding the cost. Again the whole sum may be worked in one equation; this latter course is usually the most accurate, because only one series of figures have to be dealt with, and there are not so many fractions, the answer being found at once, as follows:

$$\frac{80 \times 32 \times 48 \times 105 \times 40}{560 \times 36 \times 100} = 256d. \text{ or } 21s. 4d.*$$

Here the allowance for waste is added by simply using 100 as a denominator and 105 as a numerator, and the cost by using the price per lb. as a numerator.

Probably this would be sufficient to illustrate the rules named, but one more example may not be out of place, and in this case the working given as shortly as possible.

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\* The percentage worked out in this manner is not strictly accurate, but sufficiently near for all purposes.

*Example 2.*—Find the cost of a piece of worsted coating cloth, made as follows: warp  $2/36$ 's at  $3/8$  per lb., 76 ends per inch; weft 18's at  $2/10$  per lb., 80 picks per inch; 66 inches wide in the sley, 52 yards long, made from 60 yards of warp, allowing  $7\frac{1}{2}$  per cent. for actual waste of weft.

For warp,  $\frac{76 \times 66 \times 60 \times 44}{560 \times 18} = 1313\frac{5}{7}$ d. or  
109s.  $5\frac{5}{7}$ d. or £5 9s.  $5\frac{5}{7}$ d. as the cost.

For weft,  $\frac{80 \times 66 \times 52 \times 107\frac{1}{2} \times 34}{560 \times 18 \times 100} = 995\frac{5}{105}$ , or  
82s.  $11\frac{1}{2}$ d. or £4 2s.  $11\frac{1}{2}$ d. as cost. Therefore the whole cost of material will be

£	s.	d.
5	9	$5\frac{5}{7}$
4	2	$11\frac{1}{2}$
<hr style="width: 100%;"/>		
9	12	5
<hr style="width: 100%;"/>		

No matter what the material may be, worsted, cotton, silk, woollen, or linen, the same mode of working will answer, merely substituting the basis of the counts in the particular systems desired for those given here.

Suppose it is now required to work a back upon a cloth, as for instance, to put a woollen back upon a worsted coating cloth. The face is a known cloth, its weight, counts of yarn, and all particulars are known, and the use of the back is to increase the weight and bulk of the cloth up to a given point, it is required to find the counts of the back warp and weft which will bring it up to that point, the procedure would then be by rule 24, page 65.

*Example 3.*—A cloth made from  $2/48$ 's worsted warp, 64 ends per inch, and 18's worsted weft, 64 picks per inch; a woollen back is required to it, the ends and picks of face and back respectively

to be as 2 to 1, the relative weight of the two cloths to be as 2 to 3, that is the back cloth to be one half heavier than the face; what counts of warp and weft will be required for the back? counts to be in Yorkshire skeins. Then by rule 24

For warp  $\frac{24 \times 560 \times 1 \times 2}{256 \times 2 \times 3} = 17\frac{1}{2}$  counts of woollen warp.

Weft, by rule 24  $\frac{18 \times 560 \times 1 \times 2}{256 \times 2 \times 3} = 13\frac{1}{3}$  the counts of woollen weft.

The next form in which the question may be dealt with is when two or more materials are employed; the cloth must be of a given weight, the counts of the yarns to be employed are specified, and it is required to find the number of ends and picks per inch, to produce a cloth of the weight specified.

*Example 4.*—A cloth is to be made 62 inches broad in the reed, 50 yards long, from 56 yards of warp, the total weight of the piece must be 80lbs.,  $\frac{2}{5}$  of this weight must be in the face cloth, and  $\frac{3}{5}$  in the back cloth; counts of yarn to be as follows: face warp 2/36's worsted, back warp 2/30's cotton; face weft 14's worsted, back weft 12 skein (Yorkshire) woollen; to have 2 ends and picks of face to one of back; how many ends and picks per inch are required?

The simplest method is to first find the actual weight of face and back cloths respectively, thus:

$$\frac{2}{5} \text{ of } 80 = \frac{80 \times 2}{5} = 32 \text{ lbs.}, \text{ and } \frac{3}{5} \text{ of } 80 = \frac{80 \times 3}{5} = 48 \text{ lbs.}$$

Then proceed by rule 28 for the warp, thus:

$$\frac{560}{840} \text{ or } \frac{2}{3} \times \frac{18}{15} \times \frac{1}{2} = \frac{12}{30}, \text{ and } 12 + 30 = 42, \text{ and to find weight of face and back warp respectively.}$$

As 42:12::32lbs.:9·1lbs., weight of back warp ;  
and as 42:30::32lbs.:23lbs., weight of face warp ;  
and to find the number of threads per inch of each  
respectively, by rule 21.

$$\frac{23 \times 18 \times 560}{62 \times 56} = 66 \text{ ends per inch of face.}$$

$$\text{And } \frac{9 \times 15 \times 840}{62 \times 56} = 33 \text{ ends per inch of back.}$$

Then to find the picks per inch in the weft:

$$\frac{560 \times 14 \times 1}{256 \times 12 \times 2} = \frac{245}{192}, \text{ and } 245 + 192 = 437, \text{ then}$$

As 437:245::48:27lbs. back weft ;

And as 437:192::48:21lbs. face weft.

And next to find picks per inch of each weft  
by rule 30.

$$\frac{27 \times 12 \times 256}{62 \times 50} = 26\frac{586}{775} \text{ picks per inch of back.}$$

$$\text{And } \frac{21 \times 14 \times 560}{62 \times 50} = 53\frac{117}{155} \text{ picks per inch of face.}$$

One further illustration may be given, and in this case instead of finding the actual weight of each material to begin with, the proportion of weight may be worked in with the question, so as to present it in its most compact form. Although it makes no real difference in the working: there is no actual saving, simply the formulæ appear more compact.

*Example 5.*—A cloth is to be made 52 yards, from 60 yards of warp, and to be 68 inches wide in the reed, the total weight to be 80lbs., the warp to contain  $\frac{3}{7}$ ths and the weft  $\frac{4}{7}$ ths of the total weight, counts of warp to be, face 2/38's worsted, back 2/40's cotton, counts of weft to be, face 18's worsted, back 16 skein woollen (Yorkshire count), to have 2 ends and picks of face to 1 of

back ; how many ends and picks per inch will be required ?

$$\frac{560 \times 2/38 \times 1}{840 \times 2/40 \times 2} = \frac{19}{60}, \text{ and } 19 + 60 = 79.$$

Then as  $79:19::\left(\frac{80 \times 3}{7}\right):8\frac{1}{4}$  lbs. back warp ;

and as  $79:60::\left(\frac{80 \times 3}{7}\right):26$  lbs. face warp.

And to find ends per inch :

$$\frac{8\frac{1}{4} \times 2/40 \times 840}{60 \times 68} = 34 \text{ ends per inch nearly of back,}$$

And  $\frac{26 \times 2/38 \times 560}{60 \times 68} = 68$  ends per inch nearly of face.

Then for the weft by the same rule.

$$\frac{560 \times 18 \times 1}{256 \times 16 \times 2} = \frac{315}{256}, \text{ and } 315 + 256 = 571.$$

Then as  $571:315::\left(\frac{80 \times 4}{7}\right):25\frac{1}{7}$  lbs. back weft.

And as  $571:256::\left(\frac{80 \times 4}{7}\right):20\frac{3}{7}$  lbs. face weft.

And to find picks per inch :

$$\frac{25\frac{1}{7} \times 16 \times 256}{52 \times 68} = 29 \text{ picks per inch of back weft.}$$

And  $\frac{20\frac{3}{7} \times 18 \times 560}{52 \times 68} = 58$  picks per inch of face weft.

The next method of dealing with the question is when two materials being used, the weight the cloth is to be being given, the proportion of weight of face and back respectively, and the ends and picks per inch of each being also given, it is required to find the counts of yarn which will produce the required weight of cloth. This is a

kind of calculation which may often be required in practice, and which is very easy to carry out.

*Example 6.*—A worsted coating cloth is required to be made to weigh 24ozs. ( $1\frac{1}{2}$ lbs.) per yard as it comes from the loom, it must have 60 ends and picks per inch of face, and 30 ends and picks per inch of back, width of reed 64 inches, counts of warp and weft to be the same in face cloth, and in back cloth respectively,  $\frac{3}{7}$ ths of the total weight to be worsted, and the rest woollen.

Then by rule 26:

$$\frac{60 \times 64}{\left(\frac{1\frac{1}{2}\text{lbs.} \times 3}{2 \times 7}\right)} \times 560 = 21\frac{1}{3} \text{ counts of worsted.}$$

$$\text{And } \frac{30 \times 64}{\left(\frac{1\frac{1}{2}\text{lbs.} \times 4}{2 \times 7}\right)} \times 256 = 18\frac{7}{9} \text{ counts of woollen.}$$

In this case the counts of warp and weft in each cloth are specified as being the same, but they may be different; the warp may be lighter than the weft, or *vice versa*; either one or the other may be specified and the counts of the other found. Whichever may be specified, it will simply require the application of the rule 4, to find the second.

*Example 7.*—In the previous example, the counts of worsted, for both warp and weft is found to be  $21\frac{1}{3}$ . Instead of warp and weft being equal, let the warp be 24's; what counts of weft will be required;

To find the counts of a yarn which with one of 24's, will produce an average of  $21\frac{1}{3}$ , the following will be the formula:

$$24 \times \left(\frac{21\frac{1}{3}}{2}\right) - \frac{21\frac{1}{3}}{2} = 19\frac{1}{5} \text{ as the counts required.}$$

And to prove that this is true, find the counts resulting from the combination of one thread of 24's and one of  $19\frac{1}{5}$  by rule 4, thus:

$\frac{24 \times 19\frac{1}{5}}{24 + 19\frac{1}{5}} = 10\frac{2}{3}$ , therefore if it be  $10\frac{2}{3}$  for two threads it would be equal to an average of  $21\frac{1}{3}$  for each thread.

WHEN EACH SPLIT IN THE REED DOES NOT CONTAIN THE SAME NUMBER OF ENDS TO FIND THE ENDS IN A GIVEN WIDTH OF PIECE.

This calculation applies to a great variety of fabrics, and is one of absolute necessity in the manufacture of fancy cloths, though perhaps more in cotton or mixed dress goods than in any other. In most cases of patterns of this character there are at least two kinds of material employed; for instance if one portion of the cloth has two threads in each split, and the other portion has four ends in each split, it is probable that they will be either two materials, or two different counts of the same material, in either case it will be necessary, to find not only the total number of threads in the whole warp, but also the number of each kind of thread, this will be most readily done by the

RULE (32).—First find the number of reeds occupied by the whole pattern, and divide the number of reeds in the width of piece by the number in each pattern, then multiply the quotient by the total number of ends, or by the number of ends of each kind, in the pattern.

*Example.*—A piece is to be woven as a stripe. There are four splits with two ends in each, and two splits with four ends in each; there are 36 splits per inch, and 30 inches wide, how many ends

are there in the total? Or if the two yarns are different, how many ends are there of each?

$36 \times 30 = 1080$  reeds in the width of piece,  
 $4 + 2 = 6$  splits in each pattern, and  $\frac{1080}{6} = 180$   
 patterns in the width of piece, and as there are 16  
 ends in the pattern (4 splits with 2 each, and 2  
 splits with 4 each) there are  $180 \times 16 = 2880$  ends  
 in the whole warp. Or if ground and stripe are  
 different in colour, material, or counts, there are  
 1440 ends of each.

This is, of course, one of the simplest illustrations which could be given, but it will perhaps illustrate the principle as well as any other, and at the same time it will perhaps be as well to have one or two other examples of a more complete character; and by means of these one or two other questions can be raised in connection with the subject.

*Example.*—A stripe is to be formed as follows: 60 ends cotton, 40 ends silk, 24 cotton, 20 silk; total 144 ends. Cotton to be 2 ends in a split; silk to be four ends in a split; reed 40 splits per inch, width of piece 32 inches in the reed, how many ends of each will be required? then proceed as follows:

60 ends cotton	2 in split	=	30 splits.
40 „ silk	4 „	=	10 „
24 „ cotton	2 „	=	12 „
20 „ silk	4 „	=	5 „
144	ends	and	$\frac{1280}{57} = 22$ patterns and 23 splits over.

144 ends and 57 splits in each pattern.

Thus 32 inches by 40 splits = 1280 splits and  
 $\frac{1280}{57} = 22$  patterns and 23 splits over. These 23  
 splits must be dealt with, and it will be most



convenient to add them to the ground or cotton, then there are 84 ends of cotton, and 60 of silk in each pattern, therefore to find the ends of each it will be for cotton  $(84 \times 22) + 46$ , that is 22 patterns of 84 ends each with 46 ends (23 splits with 2 ends in each) added, or equal to 1894 ends. For the silk there are simply 22 patterns of 60 ends each, or  $60 \times 22 = 1320$  ends, thus giving a total of 3214 ends in a warp.

This question of the disposal of the surplus splits, if the term may be used, is one of the most important connected with this subject, for if a cloth *must* be a given width in the reed, and the number of splits occupied by each pattern is such as to leave a remainder, this remainder must be disposed of in the best possible manner, one of the chief considerations being to present both edges of the piece the same, and also as far as possible to arrange so that the two edges of the piece will join properly to each other, this latter object cannot always be attained but the former one always receives attention from manufacturers, so as to present the same appearance at both edges of the piece.

WHEN EACH SPLIT IN THE REED DOES NOT CONTAIN THE SAME NUMBER OF ENDS, TO FIND THE AVERAGE NUMBER PER INCH, OR THE AVERAGE SETT.

It very frequently happens that when the number of ends of each material, or the total number of ends in the warp, have been found, it is necessary to find the average number per inch, or according to some particular system, to find the sett.

The necessity for this arises when all the ends, those forming the stripe as well as the ground,

are drawn through the same sett of healds, or when the cloth must be woven with a jacquard harness. In a great majority of cases the ground and stripe will each have their own healds, but when from any cause, especially when the jacquard is brought into use, such is not the case, then it becomes absolutely necessary to find the average number of ends per inch or sett. In such cases it is necessary to find the total number of ends in the warp and then simply divide by the width of piece in inches, thus, in the example last given there are 3214 ends in 32 inches, thus  $\frac{3214}{32} = 100\frac{1}{8}$  ends per inch as the average. And similarly in any other case.

This calculation gives the average number of ends per inch for 32 inches, but it might not be the exact average for any number of inches. For instance there are a given number of patterns plus 23 reeds or 46 ends, those 46 ends are all two in a split, whereas in the full pattern a portion are four in a split. Therefore the average obtained above is not the average for one pattern or for any number of even patterns, but for 32 inches. True, the difference is but a small fraction of an end per inch, but it is well to be aware of small fractional errors and the manner in which they arise.

Although this fractional error occurs, there is no doubt this is the best method of working where the calculation is being made for a jacquard harness, for this reason, that having the total number of ends given which must be distributed over a given number of inches, the sett of the harness, or the number per inch is known, therefore taking the whole number in a given space the exact average will be shewn for the whole of that space. And as the harness cannot be made finer,

but may be made coarser by casting down, it is well to know the exact average.

If the average number per inch be desired for one pattern, or for any number of even patterns, the question will be one of simple proportion. Take the example, already used, again, there are 144 ends in 57 splits, a portion of the ends are two, and another portion four threads in a split. If the 144 ends were all two in a split they would occupy 72 splits, or if the 57 splits had each only two ends they would contain 114 ends. Again, the reed contains 40 splits per inch, which with two ends in each split would be equal to 80 ends per inch, thus to find the average per inch in one pattern as  $114:144::80:101\frac{3}{7}$ . So that the average for one or any even number of patterns is  $101\frac{3}{7}$  ends per inch, as against  $100\frac{1}{2}$ , the average per inch for 32 inches. This displays at once the discrepancy in the two systems, and also the truth of each.

If it will simplify the matter, the question may be dealt with by basing it upon splits instead of upon ends. The pattern occupies 57 splits, there are 144 ends, which if all 2 in a split, would occupy 72 splits, and there are 40 splits per inch in the reed; then as  $57:72::40:50\frac{3}{7}$  splits or  $101\frac{3}{7}$  ends per inch.

Should the sett in any particular system be required to be found instead of the ends per inch, the formulæ given under the head of setts may be combined with the above, or, having found the average number of ends per inch, reduce it to the sett of the particular system required.

In some cases it is desired to find what space a pattern may occupy when the stripe is of one given sett, and the ground of another, and that

the average shall be exactly a certain sett. For instance, if healds are in stock and it is desired to make use of them, and at the same time to produce striped cloths of a given degree of fineness, then this question would come in. Put in general terms the formulæ would be as below—let  $a$  be the size of stripe in inches,  $b$  the sett of ditto,  $c$  the average sett required, and  $d$  the sett of the ground cloth, then

$$\frac{(a \times b) - (a \times c)}{c - d} = \text{space of ground}$$

between each stripe in inches.

*Example.*—Let the size of the stripe be one inch, and contain 120 threads per inch, the ground to contain 60 threads per inch, the average to be 80 threads per inch, what space must there be between the stripes to produce this average?

$$\frac{(1 \times 120) - (1 \times 80)}{80 - 60} = 2 \text{ inches.}$$

To prove that this is true—

1	inch with	120	=	120
2	,, ,,	60	=	120
<hr style="width: 100%;"/>				
3				<hr style="width: 100%;"/>
				240

and 240 threads in three inches  $\left(\frac{240}{3}\right) = 80$  per inch.

If the two portions of the warp be composed of different materials, or different counts of the same material, and it is required to find the weight of each, treat them as two separate warps, and find the weight of each by the rules given.

## THE CALCULATIONS FOR STRIPED AND CHECKED PATTERNS.

What has just been dealt with comes, strictly speaking, under the head of striped patterns, though it does not necessarily follow that all striped patterns vary in the number of ends in each split of the reed; the stripes may be simply differently coloured threads, or even differently interwoven. What is intended to be dealt with at the present moment, is where the threads are of different colours, or it may be of different materials. This part of the subject will perhaps be best dealt with in a manner which will show the possible, and probable errors into which one may fall, rather than any particular system of calculating. Suppose a warp is to be made as a stripe, a given number of threads of one colour and a given number of another colour, it is required to find the number of ends of each in the whole warp; nothing could be easier than to find the number of stripes in the width of the piece, and multiplying this by the number of ends of each colour in one stripe, the total number of each colour will, of course, be found at once. Now it may be shown where the liability to error comes in; suppose a cloth is to be made with 60 ends per inch, to be 31 inches wide in the reed, and black and white stripes, 18 threads of each are to be found alternately, it is required to find the number of ends of each in the whole warp:  $60 \times 31 = 1860$ , the total number of ends in the warp; then the stripes being equal, one is tempted to say at once, that 930 ends of each will be required; this will be true if the number of ends in the whole pattern be a measure of the total number of ends used, but not otherwise. In this case there would be 36 ends in each pattern, and

1860 ends in the whole warp, thus  $\frac{1860}{36} = 51$  patterns and 24 ends over. Now if there are exactly equal quantities of black and white, this 24 will consist of 12 of each, but that is not sufficient to make a full stripe of each, and would not look very well to have two half stripes running up one side of the piece; nor would it look well to have a half white up one side and a half black up the other; but it would be much better to arrange it so that both edges of the piece are alike, and that would simply mean that a few more ends would be required of one colour than of the other, so as to make up full stripes. This may appear a very trifling matter, and in the particular case now mentioned, it no doubt is, but in larger patterns it is, in practice, a matter which must receive its proper attention; that being so, the best plan is to find the number of complete patterns across the piece, and if there are odd ends over, arrange them so as to make both sides of the piece alike.

It may be a little out of place to go so fully into such a matter here, as it is one of design quite as much as of calculation, but it could not very well have been omitted.

In making the calculations for checks it is only necessary to supplement the foregoing by finding the proportionate quantities of each colour, or different weft. This may be done two ways, when two colours or materials are used. First find the total quantity of weft in the piece, then by proportion the quantity of each colour, and second find the proportion of picks per inch.

First to find by proportion the quantity of each colour or material.

*Example.*—A piece contains 180 hanks of weft, there are two colours, the proportion of each being 36 and 14 respectively (the two terms will probably in most cases be the actual number of picks of each colour in one complete pattern) what number of hanks of each does the piece contain?

$36 + 14 = 50$ , then as  $50:36::180:129\frac{3}{5}$ , and as  $50:14::180:50\frac{2}{5}$ , and  $129\frac{3}{5} + 50\frac{2}{5} = 180$ , the total number of hanks.

This is the readiest and surest method, because it gives, at once, the quantity of each colour or material in the piece without the necessity of dealing with fractions.

If the weft consists of two materials, as worsted and silk, find the total quantity of yarn in the piece according to the denomination of that which is predominant, and having found the proportion of each, reduce the smaller quantity to its own denomination.

Suppose for example that in the above instance the larger quantity is worsted and the smaller quantity silk, the 180 hanks which the piece contains are of the worsted denomination, 560 yards per hank, then having found that the quantity of silk contained in the piece is equal to  $50\frac{2}{5}$  hanks of worsted, how many silk hanks will it be equal to? Silk has 840 yards per hank, thus as  $840:560$ , or as  $3:2::50\frac{2}{5}:33\frac{3}{5}$ , the number of silk hanks. In any two materials the rule will apply in an equal degree.

Second, to find the proportion of picks per inch of each material or colour.

This mode of working is not often resorted to, though it is convenient, as showing at a glance the relative quantities of each colour or material

used without dealing with the actual quantities. It is worked most readily by the following

RULE (33).—As the total number of picks in the pattern is to the number of picks of each colour or material, so is the total picks per inch to the proportionate number of each colour or material.

*Example.*—A pattern consists as follows :

20	picks	dark	colour
8	,,	light	,,
4	,,	bright	,,
4	,,	light	,,

Total 36 picks in the pattern.

There are 40 picks per inch in the total ; what is the proportion of picks per inch of each ?

On analysis there are found to be 20 picks of dark, 12 picks of light, and four picks of bright colour, then :

As 36:20::40:	$22\frac{2}{9}$	picks per inch	dark colour.
As 36:12::40:	$13\frac{1}{3}$	,,	light ,,
As 36: 4::40:	$4\frac{2}{9}$	,,	bright ,,

which = 40 picks in the total.

Then to find the quantity of yarn of each in a piece of cloth, proceed by rule 29, using the number of picks per inch as found by above.

Many people prefer to work by this method, though it involves more labour. and is not quite so accurate, unless every small fraction is dealt carefully with, as the previous one.



## TO FIND THE COST OF FABRICS.

After dealing so fully with the calculations of warps and weft it may seem unnecessary to enter further into the question of finding the cost of a piece of fabric, seeing that the quantities of the two materials of which it is composed have been found there is apparently little to do but to find the cost by the price per lb. There are, however, some other considerations, such as labour, waste, &c., which must be taken into account. For the purpose of showing as fully as possible the various factors which must be taken into account, it will be necessary to follow the raw material through all the various stages of manufacture, so as to see where the waste occurs, and where labour must be charged. No attempt will be made to estimate the amount of waste or the value of labour at any point; to do so would be most difficult as well as misleading for not only will different materials differ in the amount of waste, but different qualities of the same material will also differ in a considerable degree. Suppose wool be taken to illustrate the principle and the first calculation is made at the scouring, that is

TO FIND THE PRICE PER LB. OF SCOURED WOOL.  
THE PRICE IN THE GREASE BEING KNOWN.

This question is resolved most readily by simple proportion, but before the terms of the proportion can be known, it is necessary to know what percentage of loss will occur in the process of scouring. The method of determining this is to scour a given weight, and after the process has been gone through find what is the clean weight.

Now suppose that there are no factors to be taken into account in the calculation but the weight of greasy and clean wool respectively, and the cost price per lb. of the greasy wool; the question would be solved by the

RULE (34).—As the clean weight is to the greasy weight, so is the price per lb. paid for the greasy wool, to the cost per lb. of the clean wool; or the

RULE (35).—Multiply the greasy weight by the price, and divide by the clean weight.

*Example.*—20lbs. of greasy wool at 14d. per lb. gives when scoured 12lbs. of clean wool; what is the cost of the clean wool?

As 12:20::14:23 $\frac{1}{3}$ d. per lb.

Or  $\frac{20 \times 14}{12} = 23\frac{1}{3}$ d. per lb.

This of course is simple enough, and will apply equally to every material which requires cleansing as the preliminary process of manufacture, but there are one or two items which are not taken into account here. In fact nothing is taken into account but first cost and the relative weight of greasy and clean wool. In the process of scouring or cleansing, labour must be expended, and soap and other materials used, as well as machinery or apparatus for carrying on the operation. All these must be taken into account; the quantity of cleansing material required to cleanse a certain weight of wool, &c., the cost of labour required, the depreciation of machinery, rent, light, and water. These are items which can only be determined by conditions under which the work is carried on, and therefore fixed laws cannot be laid down; all the items must be determined by

actual experiment, and in many cases of experiments extending over a considerable period, and dealing with various classes or qualities of material.

On the other hand, there is the value of the waste product which can be utilised, and which will stand as a sett-off to the other items. This again will be a variable quantity, and like the other can only be determined by local influences or considerations.

At any rate, the simple rule given—and which is too often given to young men as being all-sufficient—must not be accepted or dealt with without the accompanying considerations being taken into account in full.

In the subsequent stages of manufacture similar considerations will be involved, though the nearer the complete or manufactured article is approached the less will be the waste and the greater the value of the labour employed. Suppose the wool or other material has to be carded, there will be some waste; there will be labour and working expenses, as well as the other charges. In this case the value of the waste product is comparatively small, so that labour and working expenses will be the chief items. When combed, the value of the so called waste products—in wool at any rate—is very great.

The “noil” or short fibres which are combed from the wool are, in many cases, worth almost as much per lb. as the original wool, so that here the chief items again are labour and working expenses. A similar remark may be made as to the spinning, the waste is comparatively small: and what there is of it, possesses some value. Again in weaving the conditions are somewhat similar, the *actual* waste of material, not, in most cases, exceeding

five, or from five to ten per cent. -When *actual* waste is spoken of, it must be distinctly understood that it means only that yarn which does not actually enter the fabric. There is another item which is often termed waste, but which more properly speaking is shrinkage. Suppose a certain quantity of yarn be spun to make a piece of fabric, and by calculation it should make the piece of a given width and length, after making an allowance, of, say, five per cent. for *actual* waste ; but when the piece is made it is found that it falls considerably short of both the width and length which the calculations showed: this is due to the shrinkage which takes place. This shrinkage may be said to be of two kinds, first, what may be termed the natural shrinkage of the yarn. Whilst the yarn is being spun it is held at some tension ; in the process of weaving—more especially in the weft—this tension is somewhat reduced, therefore there is a natural tendency for the fibres of which the thread is composed to shrink together, and thereby reduce the length of the yarn ; of course the weight remains the same, but the yarn has become heavier for a certain length, and therefore would not make the length of cloth which the calculation showed. This shrinkage will vary in quantity from various causes: the nature of the material ; the amount of twist in the yarn ; and the condition—damp or dryness—of the place in which it is kept. In making calculations for the cost of a piece, this shrinkage is very frequently reckoned with the waste, but the better plan is to treat it separately, as it varies considerably, whereas the actual waste will vary only in a comparatively slight degree, and will to a great extent depend upon whether the yarn is well or badly spun, and upon the amount of care exercised by the weaver.

What may be termed the second kind of shrinkage is brought about by the warp bending round the weft, and the weft bending round the warp, or each bending round the other. The nature and extent of this shrinkage is dependent upon the structure of the cloth, the relation of warp to weft, both as regards their relative thickness and qualities, as well as upon the pattern of the cloth itself. The nature of this kind of shrinkage, as well as its influence upon the cloth, will be fully dealt with in a subsequent portion of the work. In the meantime it is necessary that attention should be called to it here, as it influences very materially the cost of a piece of cloth. In many cases it will be found that the length of warp required to produce a yard of cloth will be found to be considerably more than a yard, at other times very little more. Again the length of weft required to produce a piece of given width is considerably greater than the width of the piece itself, or in other words the difference between the sley width—that is, the width the warp occupies in the reed or sley—and the width of the piece is very great, at other times very little; this is usually spoken of as the shrinkage in the reed.

It is very seldom that the shrinkage in both directions, that is, in the warp as well as in the weft, is very great at the same time, generally it is more marked in one direction only, and is brought about quite as much by the relation of the warp to the weft in quantity or bulk, as by the pattern of which the cloth is made.

From whatever cause this shrinkage arises, whether from the nature of the material, from the relation of warp to weft, or from the pattern, it must be carefully noted and dealt with in the calculation of cost. Fixed rules cannot be laid

down, all that can be done will be given in a subsequent portion of this work, but more reliance must be placod upon careful observance in the process of manufacture, than in any rules or laws; these rules can only be a general guide, and not taken as being absolutely true and reliable, because no rules can be laid down dealing with a question of this kind, which will meet the peculiarities of every case.

Then having, by the rules already given, found the quantities of warp and weft, having made the proper allowances for waste and shrinkage—the latter mostly deduced from practice—in determining the cost of a piece of cloth, it is only necessary to add the usual working expenses, which consist, as before, of labour, depreciation of machinery, general expenses, and so forth, and which of course will be variable under different circumstances.

No cognizance is being taken here of cost of finishing, loss of weight in finishing, and such items, these like the others are so variable in their quantities and character, as well as the value of the waste product, which may be afterwards utilized, that it would be impossible to deal with them except according to the particular circumstances attending each case.

Nothing more can be done in this than to advise the student, manager, or manufacturer, to observe carefully, and note all the conditions, and to make the utmost use of his observations, for his own guidance and protection.

## THE STRUCTURE OF FABRICS.

Having now examined the general principles upon which Textile Calculations are made, it remains to examine carefully into the principle of the Structure of Fabrics.

It will be well first to determine what is meant by the Structure of Fabrics. It may mean one of two things: the structure of the fabric as affected by the pattern; or as affected by the relations of warp and weft; or in a broader sense, and undoubtedly in the sense in which it should be taken, it may mean the combination of the two.

The general principle of the Structure of Fabrics has been already dealt with generally in my "A Practical Treatise on Weaving and Designing of Textile Fabrics," published by Messrs. J. Broadbent & Co., Huddersfield, and also in my "Design in Textile Fabrics," published by Messrs. Cassell & Co., London, as one of their "Manuals of Technology," so that it will not be necessary to enter into the general question here, but to deal with the question in a more direct manner, and take into account the actual relations between warp and weft, and between warp, weft, and pattern; and to enter carefully into the calculations, &c., required in connection with them.

To do this in the most complete and effectual manner, it will be necessary to enquire first into the relations between sett or ends per inch, picks per inch, and pattern, in the various kinds of cloth, as: *a*, plain cloth, *b*, twilled cloth, *c*, satin cloth, *d*, figured cloth, *e*, double and other cloths.

For the purpose of examining fully into the various systems affecting the structure of cloths,

two principal questions may be asked and carefully examined, viz :—

WHAT CONSTITUTES A PERFECT CLOTH? AND WHAT IS MEANT BY THE “BALANCE OF CLOTH” OR CLOTH STRUCTURE?

These two questions will be dealt with in the most satisfactory manner by taking them together, because to have a perfect cloth it must be balanced in its parts, and therefore, although the questions are put as two separate ones, they really form part of the same question. The chief reason for putting them as two questions, being, that the whole subject may be contained in them, and consequently may be dealt with in the most complete manner.

PLAIN CLOTH. Beginning first with plain cloth, and determining what will constitute a perfect cloth and what is meant by “balance of cloth,” a reliable basis will be laid down for determining what constitutes perfection, or balance, in other cloths. Plain cloth, as has been fully shown in the two works already mentioned, is formed by the warp and weft threads interweaving with each other alternately, and is therefore, apparently incapable of much ornamentation, but in both works it is shown that ornamentation may be produced by a mere alteration of the relative quantities of warp and weft. It now remains to determine not only what is a perfect plain cloth, but under what conditions, and to what extent, this alteration of the relative quantities of the two sets of threads may be made.

In a plain cloth, the interweaving of the threads taking place as described, one of three things must take place: the weft must in some degree bend



round the warp: the warp must bend round the weft: or each must be slightly bent out of its straight line. These conditions will be brought about or altered by the alteration of the relative quantities or thicknesses of the warp and weft respectively.

Take the last of these three conditions, that which represents what is usually termed a perfect plain cloth, and which is shown in section at



Fig. 1.

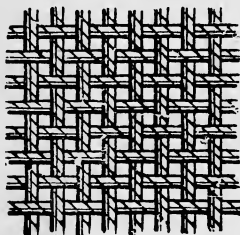


Fig 2.

Fig. 1, and in plan at Fig. 2. In this, warp and weft are equal to each other in quantity, that is, in the ends and picks per inch, as well as in their diameters. As a starting point, seeing that the warp and weft threads intersect each other alternately, that is, that each weft thread passes between each warp thread, it may be assumed that each warp thread is not only equal in diameter to the weft threads, but that the spaces between the threads are equal to the diameters of the threads themselves. This assumption though not absolutely true, is approximately so. If the weft be equal to warp, and one weft thread is passed between each warp thread, it may be assumed that the space required between

the warp threads must be equal to the diameter of the weft. This would be so if the warp threads maintained their perfectly straight line, but weft and warp being equal, each exercises equal power over the other, and therefore each is bent slightly out of its straight line, and as a consequence the space between the threads as they stand in the reed may be a little less than the diameter of the weft threads, and in like manner, the spaces between the weft threads may be a little less than the diameter of the warp threads. Now it is very evident that if a cloth be made upon this basis, warp and weft equal to each other in diameter, and in the number of threads per inch, the order of interweaving being alternate, that the balance of the cloth must be perfect; neither of the two materials preponderating over the other, either in the order of interweaving, or in their quantities, one must exactly balance the other. A cloth of this kind is sometimes spoken of as a "square" cloth, but by whatever name it may be known, it is undoubtedly a cloth which is perfect in structure.

Having determined what is perfection in a plain cloth, and which for convenience may be spoken of as a cloth in which warp and weft are equal, and in which the spaces between the threads are equal to their diameters, this may be made the basis from which all plain cloths, and also by comparison all other cloths must be made. If the character of the cloth is to be altered, although the order of interweaving be the same, it must be altered according to fixed rules, and if the order of interweaving be altered, either the same character of structure, and the same degree of perfection maintained as in the plain cloth—so far as the relations of warp and weft to each other are concerned—or the character may be altered at will.

## ALTERING THE CHARACTER OF PLAIN CLOTHS.

Having a plain cloth given which is perfect, and this perfection can be easily obtained by taking the actual diameter of the threads, it is now desired to alter the character of it by altering the relative quantities of warp and weft. In this manner, cloths are frequently ornamented, and their useful properties to some extent altered at the same time. Suppose it is desired to form a cord or rib running in the direction of the warp, this would be accomplished by altering the relative thicknesses of the warp and weft, and at the same time the relative number of threads in a given space.

Now, it would seem at first sight as if after altering the relative diameters, that the alteration in the relative number of threads should be in exactly the same ratio, but such is not the case; as has been already shown, when the two sets of threads are equal, each is bent out of the straight line somewhat, but if one set of threads be much thicker than the other, the thin thread only will be bent, and the thick one retain its straightness. That being the case there is no necessity for a space at all between the weft threads; they may be in actual contact with each other, and therefore the number of threads in one inch will be determined by their diameters only, no allowance whatever being made for space between them.

In the manufacture of this class of fabric, one of two errors is commonly committed: either the weft threads are too few, an actual space existing between them, or they are too many. In the first case, the warp threads being straight cylinders and the weft bending round them, any friction would displace them, and produce "fraying." In the second case, in attempting to put too many in, they would be subject to compression, and as

threads are not equally compressible throughout their entire length, an irregularity in the fabric would be the result; an appearance of having more picks per inch in one place than another, or what is variously known as "jamminess," "rowiness," &c. Although this kind of imperfection is mainly due to an attempt to introduce too much weft of a given size, a mistaken notion of fineness, yet it may be brought about also by having too little weft in, but this particular kind of imperfection, when the cloth is thin, is usually of a less serious character than that which results from over compression.

Then as to the warp: to produce a good cloth the space between the threads should not be much less than the diameter of the threads themselves, otherwise there is not sufficient room to allow the weft to bend easily round them, rather it is better to err in the opposite direction, and have the space somewhat greater than the diameter, because then the weft will form a less angle, can be more easily compressed, and has a better opportunity of covering the warp. This must not be carried too far, else the character of the rib will be somewhat destroyed; there will not be that roundness which is often sought, but it will assume a flatness. This relation of diameter and space cannot have too much attention paid to it, for upon it depends in no small degree the perfection of the cloth, both as regards relation of warp to weft, and as to the roundness of the rib. If larger or smaller ribs are required, the sizes and distances must be determined accurately, and for this purpose definite rules will presently be given.

Suppose now that the conditions of structure are reversed, and the weft is made thicker and the warp thinner, it will become, practically, the cloth

which has just been dealt with inverted, that is, the warp threads may touch each other, and a space exist between the weft threads to allow the crossing of the warp, so that all that has been said of relative quantities, and distances apart, will apply, but in the reverse order, read warp for weft, and weft for warp.

In this case the cloth will not necessarily be subject to some of the imperfections which have been described ; there will not be the same tendency to compression, or perhaps it will be more correct to say variable compression, upon the thin warp threads, which would apply to the weft threads ; they would be held in their position by the reed, and as for forcing in the weft by the reed, the crossing of the warp threads will not permit it beyond a certain point, yet it is none the less necessary to pay strict attention to the conditions already specified for the production of a perfect fabric. A little more liberty may perhaps be taken with the cloth, but it must not be carried too far.

**TWILLED CLOTHS.** Having found what is perfect in plain cloths, it will be easy to produce equal perfection in any twilled cloth, but to do so it will be necessary to pay careful attention to the character of the twill, as a slight alteration even in the twill, may necessitate a complete alteration in the conditions of structure.

This has been so fully laid down in the manual on "Design in Textile Fabrics" at page 37 and following pages, that it will not be necessary to do more than refer to it here.

Then suppose that from the basis of a plain cloth—and that is unquestionably the best starting

point—it is desired to produce a common twilled cloth, and it is desired to find what alteration is required in the number of ends and picks per inch, some data or mode of calculating is required.

Suppose it is required to produce the twill given at Fig. 3. Here the weft intersects the warp every two threads. The whole pattern occupies four threads—being twice repeated here—and those four threads are intersected twice by the weft. In a plain cloth the weft intersects the warp at every thread, therefore for four threads there would be four intersections. It has already been shown that the space between the threads when the intersection takes place must be *about* equal to the diameter of the intersecting thread, therefore assuming that warp and weft are equal in diameter, and taking the diameter as the unit of measurement, the four threads of the plain cloth with their spaces would occupy eight of those units; but the four threads of the twill cloth will occupy only six of the units, and therefore a greater number of threads per inch will be required to make a perfect cloth of the twilled, than of the plain fabric, and this increase will be in the proportion of six to eight. So that supposing the plain cloth contained 60 ends per inch, then to find the number of ends to make the twill perfect it would be as 6:8::60:80; or 80 ends per inch will make this twilled cloth equally perfect with the plain cloth which contained 60.

Of course what has been said of warp applies equally to weft, there being equal quantities of warp and weft on the surface, and the order of interweaving being regular, and the twill moving from end to end consecutively, warp and weft should be equal in quantity.

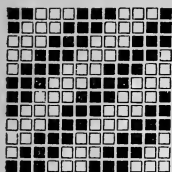


Fig. 4.

As another example take the pattern Fig. 4, in this 6 ends are occupied, the weft passing over and under 3 ends alternately, therefore in every six threads there are two intersections, and again taking the spaces for the intersections as being required to be equal to the diameters, there would be eight units of space required. Now with six ends in a plain cloth there would be six intersections, and therefore twelve units of space would be required; then to find the number of ends to make a perfect cloth with the twill, or at any rate one as perfect as the plain cloth, it would require an increase in the threads in the proportion of 8 to 12, so that supposing again that the plain cloth had 60 per inch, to find the number required for the twill, as  $8:12::60:90$ . consequently 90 ends of the same yarn will make a perfect cloth in the twill, if 60 makes a perfect one in the plain.

#### TO ALTER THE PATTERN AND RETAIN THE SAME PERFECTION OF STRUCTURE

Unless the actual diameters of the threads have been found from which data all calculations may readily be made, it may occur that a cloth has been made in some particular pattern, and it is desired for some reason to alter the pattern but to retain the same perfection of structure, for instance, a cloth may be made in the four end twill, given at Fig. 3, and either for the purpose of having a bolder twill, or to make a heavier cloth, it is desired to change to the pattern given at Fig. 4; the particulars of the first cloth are known, and it is required to make the second cloth of exactly the same character, then, using the same yarn, it is

required to find the number of ends and picks per inch to produce it. In the one cloth there are four threads and two intersections, or equal to six units, and in the second there are six threads and two intersections, or equal to eight units, then the number may be found by the formula,  $\frac{80 \times 6 \times 6}{4 \times 8} = 90$ , that is, if the first cloth had 80 ends per inch, the second would require to have 90 per inch. The whole question then may be reduced and stated as a simple rule.

IN CHANGING FROM ONE PATTERN TO ANOTHER, TO FIND THE NUMBER OF ENDS OR PICKS PER INCH TO PRODUCE A CLOTH OF THE SAME CHARACTER.

RULE (36).—As ends in the pattern of the given cloth multiplied by ends, plus intersections, in the pattern of the required cloth, is to ends in the pattern of the required cloth, multiplied by ends, plus intersections, in the pattern of the given cloth, so is the ends per inch of the given cloth, to ends per inch of the required cloth.

Take the example just given, where the pattern is changed from a four to a six end twill, the statement of the question will be

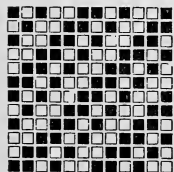


Fig. 5.

As  $4 \times (6+2) : 6 \times (4+2) :: 80 : 90$ .

Or in another form :

$$\frac{6 \times (4+2) \times 80}{4 \times (6+2)} = 90 ;$$

Or  $\frac{6 \times 6 \times 80}{4 \times 8} = 90$  ; this latter form is exactly as it is given above, and although it is no doubt



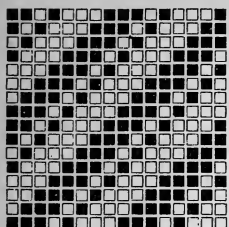


Fig. 6.

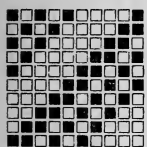


Fig. 7.

the simplest mode of working, it does not convey to the mind so completely how the result is obtained as the rule given above.

*Example 2.*—It is required to change from the pattern given at Fig. 5 to that given at Fig. 6. The cloth from Fig. 5 has been made with 72 ends per inch, how many ends per inch will be required to make Fig. 6 exactly equal to it?

The pattern Fig. 5, occupies 6 ends. Fig. 6 occupies 8 ends, there are four intersections in each, then

$$\text{As } 6 \times (8+4) : 8 \times (6+4) :: 72 : 80.$$

*Example 3.*—It is required to change from Fig. 5 to Fig. 7; the cloth from Fig. 5 has 72 ends per inch; how many ends per inch will be required to make Fig. 7 exactly equal to it?

In this case Fig. 7 has 6 intersections, and 10 ends, against Fig. 5, with 4 intersections and 6 ends; then

As  $6 \times (10+6) : 10 \times (6+4) :: 72 : 75$ , the number of ends required.

In this last example there is apparently a wide difference in the two patterns, and at first sight one would be tempted to suppose that the ten-end twill would require considerably more ends per inch than the six-end pattern, but a glance at the close interweaving in a portion of the ten-end pattern shows at once where the modifying influence is; were the intersections fewer, the number of ends required would be proportionately greater.

Take as another example the pattern given at Fig. 8, and let it take the place of Fig. 7. Here the intersections are fewer, therefore the number of ends required will be greater, this pattern has only four intersections; then

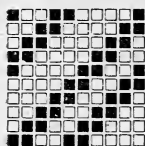


Fig. 8.

As  $6 \times (10 + 4) : 10 \times (6 \times 4) :: 72 : 85\frac{5}{7}$   
the number of ends required.

One is sometimes led to suppose that the larger the pattern, the greater the number of ends per inch required to make a good cloth. It is not the number of ends, but the number of intersections in the pattern which determines it.

Let an ordinary five end twill, with the weft passing over two and under three threads, take the place of Fig. 8, it will require exactly the same number of ends per inch as Fig. 8 does, because there would be two intersections in five threads against four in ten threads, or to give the working :

$$\text{As } 6 \times (5 + 2) : 5 \times (6 + 4) :: 72 : 85\frac{5}{7}.$$

All these examples are of fabrics where warp and weft are equal in quantity, and when the pattern is such as to permit of their bearing that relation to each other; and further, they are based on the assumption that warp and weft both bend in an equal degree. But, as shown in the Manual before referred to, there are patterns which will not permit this equal bending: patterns in which either the warp or weft lay perfectly straight in the cloth, as has been pointed out in reference to corded cloths. In many cases these patterns are simply the result of rearrangement of a simple regular twill.

The class of pattern may be easily pointed out, but the manufacturer or designer must at all times, no matter what rules are laid down, exercise care and judgment in the application of the rules.

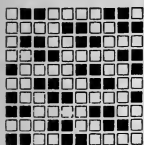


Fig. 9.

Fig. 9 is a pattern where care in the application of the rules will apply.

If it is examined it will be found that every pick interweaves exactly as they do in the pattern given at Fig. 8, yet the best results would not be obtained by making a cloth to exactly the same particulars as Fig. 8. The pattern Fig. 8, is a regular twill running constantly in the same direction, and at an angle of 45 degrees, this pattern (Fig. 9) may be made to produce a twill, but it is not upon paper a continuous one. If made to the same particulars as would suit Fig. 8, with warp and weft equal, it would present a broken appearance, but if the weft be made much thinner than the warp, and introduce more picks per inch, in fact deal with it as if making a cord cloth, then a continuous twill, approaching in appearance a straight cord, running nearly parallel with the warp will be the result.

It would be an easy matter to multiply examples, but a difficult one to give all the varying forms of twill which will necessitate an alteration in the relative quantities of the material employed.

There is one matter which must be made perfectly clear before leaving twills of the kind just dealt with. It has been said that twills running at an angle of 45 degrees may be made with warp and weft equal in quantity and in thickness, and that other twills must have an alteration in the relative thickness and in the number of ends and picks per inch, so as to produce perfection. Now it does not follow that

although twills which have not an angle of 45 degrees can only in very few instances produce perfect cloths when warp and weft are equal, that twills having that angle can only be perfect when they are equal; the relative quantities may be very much altered, and yet produce perfect cloth, exactly in the same way as in plain cloth, but the alteration must be made under strict conditions, so that the balance may be maintained between warp and weft; in fact this remark will apply to all cloths where the order of interweaving is consecutive, and the warp and weft come to the surface in equal quantities, and to a very large proportion of patterns, where the order is not consecutive, but when warp and weft come to the surface equally. The method of altering quantities and maintaining the balance of cloth, will be fully dealt with in a subsequent section of the book.

Another class of twill now requires to be dealt with, and one which is simply the result of the rearrangement of common twills, but that rearrangement completely alters the character of the cloth resulting from it, and necessitates a

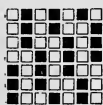


Fig 10.

complete alteration of the relations of warp and weft; Fig. 10 is an example of this kind of twill. Taking the number of intersections of the weft with the warp, at each succeeding pick the pattern appears as nearly as possible a plain cloth; but taken in the reverse direction, reading from the warp instead of the weft, the intersections are very few, being, in fact, only two. To base the calculations for the number of ends and picks required upon the number of intersections in either warp or weft, would, in this case, be quite delusive. The pattern occupies 7 ends, each weft pick intersects the warp 6 times, and each warp thread intersects the weft but twice, therefore

calculated on the basis of the weft, the number of ends per inch would be as nearly as possible equal to that of a plain cloth, whereas on the basis of the warp, it would be exactly equal to a common seven-end twill.

Now the proper way to treat this cloth is to deal with it on the principle of a cord running across the piece. The twill runs nearly parallel with the weft and, *only alternate ends* come to the surface, therefore unless they are closely placed, they could not cover the weft, and further, the warp must be thinner than the weft, so as to reduce the spaces between each thread to the lowest point possible.

The conditions of structure in Fig. 10 are exactly the reverse of those in Fig. 9, one corresponding with the weft cord and the other with the warp cord cloth. All fabrics corresponding with these two in the order of interweaving may be dealt with in a similar manner.

**SATIN CLOTHS.** In satin cloths it is an imperative condition that either warp or weft must preponderate very largely as to the number of threads in a given space, but it is not a necessary condition that they shall be equal in diameter, in fact, to make a perfect satin the reverse must be the case, the object generally is for the face material to absolutely cover the back, so that the thread must not only be as close as their diameters will permit, but as one thread is withdrawn to pass under the warp or weft at the back, the others must close over it as much as possible, for example, if an eight thread satin is being made, one out of every eight will be withdrawn for the purpose of interweaving, then to follow out the theoretical true structure, eight threads should occupy the space of seven diameters. If the material is strong and will bear friction in the formation of the shed, and

in passing through the reed, this may be carried out, but for practical purposes, if the eight threads occupy the space of eight diameters, they will spread themselves out sufficiently to cover the point of intersection; therefore this may be taken as the basis for working upon.

FIGURED CLOTHS must be treated upon the basis of the order of interweaving in the ground, with perhaps a little additional allowance for the looseness of the figures, but this cannot be very much in most cases, otherwise the ground will be too crowded, and consequently the balance of cloth will be interfered with. If the figures be merely small spots, or produced by a combination of twills running in different directions, then the intersections may be counted as in an ordinary twill, and the calculations made upon the same basis.

DOUBLE CLOTHS must be treated each one separately, as though two distinct fabrics were being produced, and too much care cannot be taken that the relation of the diameters of the threads and the number of intersections in the two cloths respectively are such that the relation between the two is perfectly harmonious. If each cloth is not *equally* perfect the result must be general imperfection, but if the relations of the diameter, the order of intersection, and the number of threads per inch be equally correct in both cloths, then the resulting cloth must be a perfect one, but otherwise it cannot be.

THE ALTERATION OF THE RELATIVE QUANTITIES OF WARP AND WEFT, AND RETAINING THE BALANCE OF STRUCTURE.

Having now dealt with the general principles which determine the relation between ends per

inch, picks per inch and pattern, it becomes necessary to discover some rule or definite method of altering the relative quantities of the two sets of threads in any pattern and yet retain the true balance of structure, or to speak more explicitly the true relation between weft and warp. In one respect this is a matter of some difficulty and I am fully conscious of the great responsibility I am incurring, and the criticism I am inviting in attempting to deal with such a subject. Hitherto no attempt has been made to reduce the question to anything like definite terms, and although all the rules which are now about to be dealt with are the outcome of careful observation, and the result of a great many experiments, yet it would be assuming too much, to say that in some respects they are infallible, at the same time there is no need for hesitating to say that in principle they are absolutely correct; any faults which may exist, are not due to want of truth in the principles, but to want of accuracy in the particular observations and measurement made of threads and their relation to each other.

Then to commence with plain cloths, it has been shown that for a perfect, or "square" cloth, warp and weft must be equal to each other, and also, that each sett of threads will be bent in an equal degree, and that upon any departure from this being made the bending must take place in one set of threads only.

Now before going further it will be well to point out certain exceptions to this general rule, let it be distinctly understood that their first application is to cloths in which warp and weft are *both of the same material*, and it will apply also to the great majority of cloths in which both are not of the same material; yet there are a few exceptions, and these exceptions will occur when some special

effects are to be produced, and when the materials of which they are made lend themselves readily to an alteration of the conditions. Take for example some of the mixed dress goods which are made from cotton warps and worsted, or alpaca, or other bright wefts. In those goods a special object is aimed at; all the brightness of the yarn must be displayed to the best advantage. Now if all the yarn from which the reflections of light are obtained are laid perfectly straight, the reflection of light upon which the beauty of the goods depends will be of a somewhat metallic character, but if the weft forms a series of corrugations, or ridges, then each corrugation forms a reflection surface. As an illustration, take any highly polished flat surface, as a steel plate or glass mirror, throw a light upon it, and although the bright polish of the whole surface is visible there is but one reflection. On the other hand let this reflecting surface, instead of being flat, be a corrugated one, then the reflections are numerous, and the effect is more brilliant. Or further, look at a lake or pool of still water in the moonlight, there is one reflection; cast a stone into it, and cause its surface to be rippled, then there are thousands of reflections. To return to fabrics, take two made from silk, one of a satin structure, which presents a highly polished flat surface, and the other forming ribs, either across or in the direction of the length of the piece; the brightness, or lustre, presented by the two is of a totally different character.

In exactly the same manner, in dealing with goods made from bright worsted or alpaca, or other such yarns, the object is to produce those corrugations, and for that purpose the diameter of warp and weft must bear such relations to each other, and the distance apart of the warp must be



such, that the angle formed by the weft in passing over and under the warp threads are of a fixed kind.

It is not easy to estimate or measure this angle exactly, but careful observation tends to show that it should be about 60 degrees. It is a fact well known to makers of these goods, that when a good cloth has been obtained—one which gives the best possible lustre—that any attempt to alter it, even in the direction of making it finer, and although even better material be employed, that in many cases the lustre is in a great measure lost. This of itself proves that the angle formed by the weft plays a part in the appearance of the fabric. It will be the object of some of the rules to be given here, to show how the cloth may be altered, and yet all its best features retained.

Then as to the relations of warp and weft in the particular cloths under consideration, differing from the general rules laid down; it must be shown how the formation of these corrugations or ridges of the weft are formed, or assisted in their formation to understand why a departnre should be made.

As the goods come from the loom, they, in many cases will probably agree, to a great extent, if not entirely with the description given of a plain cloth, where warp and weft threads are both slightly bent out of the straight line, but in the process of finishing, the warp threads are drawn out to as nearly as possible a straight line, thus causing the weft threads to be more bent, and so increasing the depth of the corrugations, and in fact in such a manner, that if the weft threads be not at least as thick—better if they are much thicker—than the warp, an appearance approaching a cord will be the result. Now this would present corrugations in one direction only, but if the

threads are thick, then they are presented in both directions, because the mere bulk of the thread alone will produce ridges—there will be a space between each one. Therefore the conditions of structure will separate cloths of this description, and also all cloths were special circumstances or conditions exist, from the general rules and conditions laid down; but the departure, the difference between warp and weft must not even in those cases, be very far from the relations pointed out as existing in the evenly balanced cloth, otherwise the cloth will not be a satisfactory one.

Although in these special circumstances a departure is made from the relations mentioned, yet the general rules about to be given are equally applicable to all cloths, and therefore will not require modification or alteration, no matter what class of fabric they are applied to.

In dealing with yarns of every description, as has been shown in the first section of this work, their relative sizes are indicated by counts, and they are always spoken of by the numbers which indicate their counts; now these counts represent the weight or solidity of the yarn, or their sectional area, but for all purposes connected with the structure of cloth, their *diameters* must be considered. It has been shown at page 46, that the diameters of yarns vary, not as their counts, but as the square roots of their counts, therefore if one yarn is double the weight of another, its diameter is not double that of the other, but as the square of the respective counts.

Suppose then that a perfect cloth has been made, say of a plain fabric, one in which warp and weft are exactly equal, and it is desired to alter the relative quantities in any possible direction. There are three ways in which the cloth may be

altered : 1st by altering weft only ; 2nd by altering warp only, and 3rd by altering both weft and warp.

Now it is very evident that in whichever of the three ways the alteration is to be made, that a thicker yarn will require fewer threads in a given space, and a thinner yarn will require more ; then the only question is, in what ratio must the increase or decrease be made ?

It has already been demonstrated, that whatever alteration be made, if the character of the cloth must be maintained that the relation of the diameters and distances apart of the thread must be preserved, therefore the diameters varying as the square roots of their counts ; the whole may be summed up in the

RULE (37). . As the number of threads in the given cloth is to the number of threads in the required cloth so is the square root of the counts of yarn in the given cloth to the square root of the counts of yarn in the required cloth.

If the counts are given, to find the number of threads, then the rule will be

RULE (38).—As the square root of the counts of yarn in the given cloth, is to the square root of the counts of yarn in the required cloth, so is the number of threads in the given cloth, to the number in the required cloth.

*Example 1.*—A cloth made with 80 threads per inch of 36's yarn, is required to be changed to one

with 70 threads per inch ; what counts of yarn will be required to preserve the same character ?

By rule 37:

As  $80:70::\sqrt{36}:\sqrt{x}$ , which will be equal to  $27\frac{9}{16}$ , therefore  $27\frac{9}{16}$  is the counts sought.

*Example 2.*—A cloth is made with 60 threads per inch of 16's yarn, it is required to make one with 25's yarn ; how many threads per inch will be required ?

By rule 38:

As  $\sqrt{16}:\sqrt{25}::60:x$ , the number of threads required.

As the square roots of 16 and 25 are 4 and 5 respectively, the working will be

As  $4:5::60:75$ , so that 75 is the number of threads required.

It will be observed that in both these examples, the numbers of which the root is required are such, that there is not much trouble in extracting, but all numbers are not quite so easy and simple. very frequently some awkward fractions may have to be dealt with ; then it is better if the working of the rule can be simplified, so as to avoid this, therefore the following rules may be substituted for those given, and will produce exactly the same result.

**RULE (39).**—As the number of threads per inch squared in the given cloth, is to the number of threads per inch squared in the required cloth, so is the counts of yarn in the given cloth to the counts of yarn in the required cloth.

Or if the counts are given to find the number of threads by

RULE 40.—As the counts of yarn in the given cloth, is to the counts of yarn in the required cloth, so is the number of threads per inch squared in the given cloth, to the number of threads per inch squared in the required cloth.

Take again the example given in illustration of rule 37, when the change is made from 80 threads of 36's to 70 threads per inch, by rule 39 it will be

As  $80^2:70^2::36:27\frac{9}{16}$  the counts required; and the example given to illustrate rule 38, worked by rule 40 will be

As  $16:25::60^2:\times^2$ , which will be 75, the number of threads required.

To those not accustomed to dealing with the square root, the working of this may be a little further explained, thus:  $60^2=60\times 60=3600$ , then as  $16:25::3600:5625$ , and the square root of 5625 is 75, obtained thus:

$$\begin{array}{r}
 5625(75 \\
 \underline{49} \\
 145)725 \\
 \underline{725} \\
 \dots
 \end{array}$$

These rules are of course equally applicable to both warp and weft, so that whether the alteration is to be made in the warp or weft there is no difference in their application, and if the alteration is to be made in both, then they will be applied to each separately.

In the exceptional cases of lustre and other goods which have been mentioned, it is of course necessary to find some one cloth, in which warp and weft bear such relation to each other as will produce exactly the angle of curvature in the weft which is desired, this may be done either by experiment or from the actual diameters of the threads, and having obtained that data, the rules will apply in all cases ; of course it must be clearly understood in reference to this particular class of cloth, that whatever alteration is made in the weft an alteration must be made in the warp, otherwise the angle cannot be preserved.

Suppose for instance, that a thicker weft is to be used, then either the warp must be thinner, or the threads further apart, or the angle will necessarily be altered ; the best way to deal with the matter is to set them further apart, in fact, to alter both warp and weft in the same ratio, then the balance of cloth is maintained.

In cloths of the cord or rib type, as clearly shown, there must be a complete alteration of the relations of warp and weft, one sett of threads must be made thicker and set further apart, and the other must be made thinner and set closer together. The only safe and definite rule which can be laid down in reference to this class of cloths, is that the thicker threads, or those which are to be laid in the cloth perfectly straight, and around which the other must bend, must not have a less space between them than the diameter of the thread itself, or if it is less, it must be very slightly so. The thinner threads, or those which bend around the straight ones, should have their circumferences touching at the point of intersection, and subjected

only to very slight compression, otherwise irregularities in the texture of the cloth will occur. Having obtained a perfect cloth upon this basis, any alterations of the number of threads per inch, or counts of yarn, must be made in accordance with the rules laid down. Of course the remarks made here respecting corded cloths, will apply equally to twilled and other cloths when the conditions of the relations of warp to weft are similar to those in corded cloths.

#### THE DIAMETERS OF THREADS OF DIFFERENT COUNTS.

In order to be able to make a proper use of what has already been said, and more especially of some of the rules which are to follow, it is necessary that the actual diameters of threads should be known, or at least as near as they can be arrived at.

This is a subject which is surrounded with some little difficulty, for as far as I can ascertain, no systematic attempt has hitherto been made to determine the actual diameters of threads of different materials, consequently although the tables given here have been made with considerable care, and as the direct result of actual observation, there is a possibility of their being slightly inaccurate, so far as the first measurement is concerned, in any one of the materials given, but in all probability this inaccuracy will be such as not in the slightest degree to affect their value for practical purposes, in fact, every care has been taken, as will shortly be shown, to make them as reliable as possible in their application to practice.

The following are the tables:—

TABLE SHOWING THE RELATIVE DIAMETERS OF  
COTTON YARNS FROM 200'S TO 1'S.

The diameters are given in figures which represent the number that would lie side by side in one inch; thus 370 represents that the diameter of the thread opposite which it is placed is the  $\frac{1}{370}$ th of an inch.

Counts	Diameter	Counts	Diameter	Counts	Diameter	Counts	Diameter
200	370	80	234	34	152	13	94 $\frac{1}{3}$
190	361	75	226	32	148	12	90 $\frac{1}{2}$
180	351	70	219	30	143	11	87
170	341	65	211	28	138	10	83
160	331	60	202	26	133	9	79
150	320	55	194	24	128	8	74
140	309	50	185	22	123	7	69
130	297	48	181	20	118	6	64
120	285	46	177	19	114	5	58 $\frac{1}{2}$
110	274	44	173	18	111	4	52 $\frac{1}{3}$
100	261	42	170	17	108	3	45 $\frac{1}{3}$
95	255	40	165	16	104 $\frac{1}{2}$	2	36 $\frac{1}{2}$
90	248	38	162	15	101	1	26 $\frac{3}{4}$
85	241	36	157	14	98		



TABLE SHOWING THE RELATIVE DIAMETERS OF  
WORSTED YARNS FROM 120'S TO 1'S.

The diameters are given in figures which represent the number that would lie side by side in one inch; thus 234 represents that the diameter of the thread opposite which it is placed is the  $\frac{1}{234}$ th of an inch.

Counts	Diameter	Counts	Diameter	Counts	Diameter	Counts	Diameter
120	234	58	163	32	120	13	77
115	229	56	160	30	117	12	74
110	224	54	157	28	113	11	71
105	219	52	154	26	109	10	67
100	213	50	151	24	104	9	64
95	208	48	148	22	100	8	60
90	202	46	145	20	95	7	56
85	197	44	141	19	93	6	52
80	191	42	138	18	90	5	48
75	185	40	135	17	88	4	42 $\frac{2}{3}$
70	179	38	131	16	85	3	37
65	172	36	128	15	83	2	30
60	165	34	124	14	80	1	21 $\frac{1}{2}$

TABLE SHOWING THE RELATIVE DIAMETERS OF  
WOOLLEN YARNS FROM 60'S TO 1'S  
(YORKSHIRE SKEIN COUNT).

The diameters are given in figures which represent the number that would lie side by side in one inch; thus 104 represents that the diameter of the thread opposite which it is placed is the  $\frac{1}{104}$ th of an inch.

Counts	Diameter	Counts	Diameter	Counts	Diameter	Counts	Diameter
60	104.058	36	80.603	24	65.812	12	46.536
58	102.309	35	79.601	23	64.425	11	44.555
56	100.530	34	78.332	22	63.010	10	42.481
54	98.718	33	77.171	21	61.570	9	40.301
52	96.873	32	75.993	20	60.078	8	37.996
50	94.992	31	74.796	19	58.553	7	35.432
48	93.072	30	73.580	18	56.995	6	32.906
46	91.113	29	72.343	17	55.389	5	30.039
44	89.110	28	71.085	16	53.735	4	26.867
42	87.061	27	69.833	15	52.029	3	23.268
40	84.963	26	68.537	14	50.265	2	18.998
38	82.812	25	67.168	13	48.437	1	13.433

TABLE SHOWING THE RELATIVE DIAMETERS OF  
WOOLLEN YARNS FROM 60'S TO 1'S  
(WEST OF ENGLAND COUNT).

The diameters are given in figures which represent the number that would lie side by side in one inch, thus 116·625 represents that the diameter of the thread opposite which it is placed is the  $\frac{1000}{116625}$ th of an inch, or practically there would be 117 in one inch.

Counts	Diameter	Counts	Diameter	Counts	Diameter	Counts	Diameter
60	116·625	36	90·117	24	73·580	12	52·029
58	114·585	35	88·856	23	72·031	11	49·814
56	112·507	34	87·578	22	70·449	10	47·495
54	110·388	33	86·280	21	68·828	9	45·058
52	108·307	32	84·963	20	67·162	8	42·480
50	106·204	31	83·625	19	65·468	7	39·738
48	104·058	30	82·265	18	63·723	6	36·790
46	101·867	29	80·882	17	61·927	5	33·584
44	99·628	28	79·476	16	60·078	4	30·039
42	97·342	27	77·400	15	58·170	3	26·014
40	94·991	26	76·584	14	56·197	2	21·240
38	92·586	25	75·097	13	54·153	1	15·019

TABLE SHOWING THE RELATIVE DIAMETERS OF  
WOOLLEN YARNS FROM 60'S TO 1'S  
(GALASHIELS COUNTS).

The diameters are given in figures which represent the number that would lie side by side in one inch, thus 91·975 represents that the diameter of the thread opposite which it is placed is the  $\frac{1000}{91975}$ th of an inch, or practically there would be 92 in one inch.

Counts	Diameter	Counts	Diameter	Counts	Diameter	Counts	Diameter
60	91·975	36	71·244	24	58·174	12	41·131
58	90·429	35	70·247	23	56·943	11	39·381
56	88·856	34	69·236	22	55·676	10	37·548
54	87·255	33	68·210	21	54·413	9	35·662
52	85·624	32	67·169	20	53·102	8	33·583
50	83·985	31	66·111	19	51·757	7	31·415
48	82·265	30	65·036	18	50·377	6	29·085
46	80·533	29	63·943	17	48·957	5	26·551
44	78·763	28	62·831	16	47·560	4	23·748
42	76·932	27	61·699	15	45·987	3	20·566
40	75·097	26	60·545	14	44·457	2	16·792
38	73·196	25	59·370	13	42·812	1	11·874

TABLE SHOWING THE RELATIVE DIAMETERS OF  
LINEN YARNS FROM 200'S TO 1'S.

The diameters are given in figures which represent the number that would lie side by side in one inch, thus 220 represents that the diameter of the thread opposite which it is placed is  $\frac{1}{220}$ th of an inch.

Counts	Diameter	Counts	Diameter	Counts	Diameter	Counts	Diameter
200	220	80	139	34	91	13	56
190	214	75	135	32	88	12	54
180	209	70	130	30	85	11	51
170	203	65	125	28	82	10	49
160	197	60	120	26	79	9	46
150	190	55	115	24	76	8	44
140	184	50	110	22	73	7	41
130	178	48	108	20	70	6	38
120	170	46	105	19	68	5	35
110	163	44	103	18	66	4	31
100	155	42	101	17	64	3	27
95	152	40	98	16	62	2	22
90	147	38	96	15	60	1	15½
85	143	36	93	14	58		

It will be necessary now to give some explanation of the manner in which those tables have been computed. In the first place, taking cotton for the purpose of showing how the diameters have been arrived at, a large quantity of yarns have been collected from the ordinary yarns of commerce, not spun specially for this purpose. Taking them in the order of their counts, a series of ten, and in the fine yarns twenty, measurements were made with a micrometer, then the average of those ten, or twenty measurements was taken, so as to obtain a mean between the thinnest and thickest part of the same thread. After the various counts have been measured, and the mean measurement found in this way, the diameter of each count in succession was found, by calculation, from that of the highest number, and compared with the mean found by actual measurement. Each count in succession was in the same manner made the basis of calculation for finding what should be the diameter of each of the others. Then again, from all the diameters so found, the average, or mean was again taken, in all cases the calculations being made to the third place of decimals, so practically working to the one-thousandth part of an inch, and consequently correcting the errors by taking the average diameters from the calculations to the same extent, and so reducing them to as near absolute accuracy as it seems possible to do.

In cotton, worsted, and linen, it will be observed that the diameters are given in full numbers, the reason being, that woollen yarns being so much thicker for the same numbers, it was thought to be better to give their actual diameter to the smallest fraction, whereas in the others, whenever a fraction has occurred, if the fraction was less than half it was ignored, if more than half it was made a whole

number ; but it must be distinctly understood that this has been done in the table only, and not in the working of the calculations.

THE RELATIVE DIAMETERS OF YARNS OF DIFFERENT MATERIALS.

A glance at the tables discloses the fact, that for yarns of the same number in different materials, there is a great difference in the diameters, for instance, 60's linen has a diameter of a one-hundred and twentieth part of an inch, Galashiels woollen one ninety-second part, West of England a one hundred and seventeenth part nearly, Yorkshire woollen, a one hundred and fourth part, worsted, a one hundred and sixty-fifth part, and cotton a two hundred and second part.

At first sight, this difference would appear to be due to the difference of the material from which the yarn is made, but in reality, with the exception of the woollen as against the other yarns, it is due to the different systems of counting, that is, if the worsted, cotton, and linen, were reduced to the same system of counting, the diameters of threads of the same count would be found to be the same.

It will be worth while for a moment to discuss this question further, as the observations of others might not quite agree with this, for instance, Mr. Barlow, in his excellent work on "The History and Principles of Weaving," says "Threads composed of different substances vary greatly in size in proportion to their weight, and in this respect the difference between the weight of cotton and linen is very apparent, yet, extraordinary as it may appear, Dr. Ure came to the conclusion that the *specific gravity* of cotton and linen were alike, when the air was expelled from between the fibres of both substances, and he believed that all

vegetable fibres had about the same specific gravity, viz., 1.50, or  $1\frac{1}{2}$  times the weight of water."

"The animal fibres, such as silk and wool, he found to have a specific gravity of about 1.30, or nearly  $1\frac{1}{3}$  the weight of water, and he concluded that all animal fibres might be the same."

Now if the specific gravities of the fibres be the same, why should there be a great difference in the diameters of threads of the same weight? Such a thing could only be accounted for by the fact, that the cotton fibre is more flexible than flax, and would therefore become more closely embedded together in the thread.

Another authority, Mr. Joseph Beaumont, in his work "Mathematical Sleaving Tables," published at Dublin in the year 1712, a copy of which is in the British Museum, says, in reference to objections taken to those tables, one was "take a pound of flax that grew in a rich soil, and spin it to a certain length, then take a pound of flax that grew in a poor and hungry soil, and spin it to the same length, the rich flax shall look finer than the poor flax, yet weigh the same."

"This objection was urged with great confidence, as matter of fact, though the objectors could not prove it by any single experiment they had made; and since many experiments I have made incline me to believe the contrary; I hope I may with equal modesty and more reason deny what they affirm."

"The objectors know nothing of the specific gravity of vegetables, though they borrow the objection from thence, for they would say a vegetable would increase in the specific gravity if it be removed to a richer soil, which is false, for that never changes or alters, though the soil be changed several times."



He further argues, that if a slight difference of specific gravity should occur, the various cleansing processes which the "flax and yarn go through before it is brought to the loom" would reduce the difference.

The experiments which have been made in preparing the tables given here tend to show that the diameters of linen threads are similar to those of cotton, when the counts are reduced to the same value. There is certainly a much greater variation in the diameter of a given thread of linen than will be found in cotton, and this greater variation may tend to produce the impression that the thread is thicker, because the thicker parts would strike the eye most readily.

The experiments tended to show also that the diameter of a worsted thread, had a slightly greater diameter than cotton and flax of the same counts or weight, when the twists per inch were similar, but many threads spun from the finest wool gave practically the same diameters as the other two materials, so that the table has been made from this basis, though no doubt yarns made from the coarser wools, where the fibres do not lay so intimately together, would present a somewhat larger diameter, but for all practical purposes it would not materially affect the result.

Woollen yarn unquestionably presents a thicker thread for the same weight, but this is no doubt due to its structure, the fibres not being laid parallel to each other, as in the other yarns, but crossing each other and projecting from the thread in a considerable degree. The variation in the diameter of a woollen thread is very great indeed, but for the purpose of arriving at truth as near as possible, a large number of measurements have been made.

Spun silk may be practically treated as cotton, so far as its diameter is concerned, for although its specific gravity, according to Dr. Ure, is slightly different, the thread will be affected only in a slight degree, more especially seeing that the system of counting, and the structure of the thread is the same in both cases; such being the case the table for cotton will answer also for silk.

THE INFLUENCE OF TWIST UPON THE DIAMETER OF  
A THREAD.

There is but one matter which apart from the structure, appears to influence in a very great degree the diameter of a thread; that is the twist. Of course the more firmly a yarn is twisted, the less its diameter, and *vice versa*, but it may be well to see what influence this will have upon the cloth.

Warp yarns are almost invariably twisted more firmly than weft, but in the process of weaving the weft can be subject to a greater degree of compression than the warp can, thus compensating for the absence of twist. This is a matter which should always be borne in mind in making a cloth, for the softer the yarn is, the softer will the cloth be to the touch, and if desired, when the fibres are not brought closely together in the thread by twisting, they may be by compression in the cloth, and at the same time, compression cannot go beyond a certain point, therefore any attempt to put more than a certain quantity of yarn into a cloth by mere force must necessarily end in failure, and whenever this compression is carried to its fullest extent, the cloth must necessarily be hard and firm to the hand, but on the other hand, if thrown too loosely together, it will be soft and flimsy.

Mr. Beaumont, in the work already quoted, upon this point observes, "if there be too few threads in the warp or breadth, it will be a sleazy, weak, unserviceable cloth, and if there be too many it will be stubborn and fret in the weaving, and look coarser than really it is."

Of course there are some cloths where softness is aimed at, and others when the reverse is the case, but there is a limit to which it must be carried in either direction.

THE DIAMETER OF ONE COUNT OF YARN BEING GIVEN, TO FIND THE DIAMETER OF ANY OTHER COUNT OF SIMILAR YARN, OR IN ANY SYSTEM OF COUNTING.

Having obtained the diameter of any yarn in one count, it becomes an easy matter to find the diameter of any other counts, of the same yarn, or in any system of counting.

It has already been shown, that the counts of yarn represent inversely their sectional areas, and that therefore their diameters vary inversely as the square roots of their counts, then from this to find the diameter of one count, the diameter of another count being given, the following will be the

RULE (41).—As the square root of one count of yarn, is to the square root of another count of yarn, so is the diameter of the first yarn to that of the second yarn, inversely. Or

RULE (42).—As the count of one yarn is to the count of another yarn, so is the diameter of the first yarn squared, to the diameter of the second yarn squared, inversely.

For convenience of working, the diameter of the thread may be reduced to a decimal part of an inch, or better, as is done in the tables, to a fraction of an inch, whose numerator is one, in that case there is little trouble with it; as being a fraction of an inch, and not reckoned by units, the proportion may be taken direct, and the answer will represent the number of threads which would occupy one inch, because the higher the number, the thinner the thread, and therefore the greater the number required to cover one inch.

*Example 1.*—A thread of 32's worsted has a diameter of  $\frac{1}{120}$ th part of an inch, (or in other words, 120 threads side by side would cover an inch), what is the diameter of a thread of 44's?

$$\text{As } \sqrt{32} : \sqrt{44} :: 120 : x = 141.$$

$$\text{Or as } 32 : 44 :: 120^2 : x^2 = 141.$$

Or to give the complete working: 120 squared is  $120 \times 120 = 14,400$ ; then

As  $32 : 44 :: 14,400 : 19,800$ , and the square root of 19,800 is 141 nearly.

In this case the answer is  $\frac{1}{141}$  of an inch, or that 141 will cover one inch.

*Example 2.*—A 20 skein (Yorkshire) woollen thread, has a diameter of  $\frac{1}{60}$  of an inch, what is the diameter of a 10 skein thread?

$$\text{As } 20 : 10 :: 60^2 : x^2 = 42.481, \text{ or } \frac{10000}{42481};$$

$$\text{Or to give the full working, } 60 \text{ squared} - 3600.$$

Then as  $20 : 10 :: 3600 : 1800$ , and the square root of 1800 is 42.481; therefore forty-two and a half threads nearly would cover one inch.

*Example 3.*—A thread of 40's linen has a diameter of  $\frac{1}{98}$ th of an inch, what is the diameter of a thread of 20's.

$$\text{As } 40 : 20 :: 98^2 : x^2 = 70, \text{ or } \frac{1}{70} \text{th of an inch.}$$

Or to give the working in full:  $98$  squared is  $98 \times 98 = 9604$ ; then

As  $40:20::9604:4802$ , and the square root of  $4802$  is  $70$  nearly; therefore  $70$  threads would cover one inch.

When it is required to find the diameter of a thread in a different system of counting, it is only necessary to reduce both the counts to the same value or denomination, and proceed in exactly the same manner, for if they are both brought to the same value, that is, their counts reduced to the same basis, the process of course becomes exactly identical with the above.

The question may be stated all in one formula if desired, but it makes no matter whether this is done or not, except for having it in a more compact form:

*Example.*—The diameter of a  $28$  skein (Yorkshire) woollen is  $\frac{1}{71}$  of an inch; what is the diameter of a  $20$  skein (West of England) yarn?

The relative values of the two systems of counting is as  $256$  Yorkshire, to  $320$  for West of England, therefore for the same weight of thread, the latter will be a lower count; then to reduce them both to the same value, bring the  $28$ 's Yorkshire to West of England, thus: as  $320:256::28:22.4$ , and to find the diameter of the  $20$ 's it will be

$$\text{As } 22.4:20::71^2:\times^2=67.$$

It will make no difference if the West of England be reduced to Yorkshire counts, thus:

As  $256:320::20:25$ , or  $25$ 's Yorkshire is equal to  $20$  skein West of England yarn; then to find the diameter:

$$\text{As } 28:25::71^2 \times^2 = 67.$$

Stated in one complete formula it will amount to exactly the same thing, thus:

$$\text{As } (28 \times 256):(20 \times 320)::71^2 \times^2 = 67.$$

For simplicity, and to make the matter more intelligible, this latter formula might be stated as a rule, and at the same time it will be more handy for reference.

**RULE (43).**—As the counts of the given yarn multiplied by the basis of its counts system in yards, is to the counts of the required yarn multiplied by the basis of its counts system in yards, so is the diameter of the given yarn squared, to the diameter of the required yarn squared.

*Example.*—The diameter of a thread of 20 skein Yorkshire yarn is equal to  $\frac{1}{60}$ th part of an inch, what is the diameter of a 30 cut yarn, Galashiels count.

The relative value of the Yorkshire and Galashiels count is as 256 to 200; then

$$\text{As } (256 \times 20) : (200 \times 30) :: 60^2 : x^2 = 65.$$

It is probably in most cases best to work by this rule, as there is less liability to having an awkward fraction to deal with.

These rules will of course apply to any yarn, whether they are of similar systems of counting or not.

**THE DIAMETER OF ONE COUNT OF YARN BEING GIVEN TO FIND ENDS OR PICKS PER INCH OF THAT OR ANY OTHER COUNTS OF SIMILAR YARN, TO MAKE A PERFECT CLOTH IN ANY PATTERN.**

It now remains to make some practical use of the tables of diameters of yarns in the production of fabrics, and to make use of them in such a manner as to ensure at all times the production of

a perfect cloth, or as near perfect as possible, without leaving anything to chance, accident, or trial.

It has been shown at pages 121 to 128, how to increase or decrease the number of threads in a given space to suit the pattern; it has been shown in the tables just given what are the actual diameters of yarns, as near as they can be ascertained; it is now necessary to combine the two, and point out the relation between them and the perfect structure of cloth.

Before laying down any fixed rules or laws relating to this subject, it may not be amiss to examine what has been done in this direction before, and compare with the present attempt to bring the subject within definite rules.

So far as can be ascertained, the only serious attempt in this direction is made in the work already quoted, of Mr. Joseph Beaumont, and published so far back as the year 1712, and curiously enough, the deductions which he makes, and which are evidently made from observations and experiments with cloths, and not from any attempt to measure the actual diameter of threads, will be found to, as near as possible, coincide with the deductions to be made from these measurements, although he has evidently fallen into several errors: but they are errors which do not in the slightest degree affect the result, as will be presently shown.

He says, "all yarn by Act of Parliament is to be reeled in hanks or dozens, each hank to contain three thousand six hundred yards and no more."

"It is found by many experiments, that such a hank weighing four ounces, must be wrought in a thirteen hundred and a half reed, that is to say, two thousand seven hundred of those threads must be in a cloth, a yard broad, made of that yarn."

“Therefore the diameter of that yarn is equal to the two thousand seven hundredth part of a yard.”

He later on appends a note, as follows:—  
 “all reeds that are used according to these tables are to be one-tenth part wider that you design your cloth and the warping bars of the same proportion, that is to say, you must allow forty inches of chain, or warp, for every yard of cloth you design to make, because the tenth part will shrink in the weaving and whitening.”

“And take this for a constant and infallible rule, that two dozen and a half of true counted yarn will make warp and weft twenty yards long, for an hundred in the reed, at any pitch whatever.”

He here makes his standard the hank or dozen, of three thousand six hundred yards weighing four ounces. At the present time, the dozen does not appear to be recognized, but the count is based upon the single lea of 300 yards, therefore the dozen leas of three thousand six hundred weighing four ounces, would be equal to 14,400 yards per lb., this would then be equal to 48 leas of 300 yards each, or what is now called 48 lea yarn.

Further, if as he says, “the diameter of that yarn is equal to the two thousand seven hundredth part of a yard,” and his yard consists of forty inches in the reed, then the diameter of each individual thread would be  $\frac{2700}{40} = 67\frac{1}{2}$ , or equal to  $\frac{10}{675}$  of an inch, or in other words  $67\frac{1}{2}$  of those threads side by side would cover an inch.

In the table given here, the diameter of a thread of 48 lea yarn is given at  $\frac{1}{108}$ , or 108 would cover one inch; now here is, apparently, a very wide discrepancy, yet as a matter of fact, when properly examined, the two agree as nearly as possible.



The rules laid down by Mr. Beaumont are evidently all intended for plain cloths. Now it is well understood that in plain cloth, weft and warp intersect each other alternately, therefore *there must be a space between the threads* to permit this intersection. It has already been shown that, theoretically, this space should be equal to the diameter of the thread itself, but practically, it must be something less than that, because both weft and warp are bent out of their straight line, and both being bent in an equal degree, the space between the warp threads and the weft threads respectively, must be *less than their diameters*.

Assuming, for a moment, that the space is to be equal to the diameter, Mr. Beaumont has made no allowance whatever for space, but has assumed that because two thousand seven hundred threads occupying forty inches, produces a perfect cloth, that the diameters of the thread must be the two thousand seven hundredth part of a yard of forty inches; whereas if the space between the threads must be equal to their diameters, the actual diameter of the thread would be reduced by one half, or equal to one five thousand four hundredth part of a yard of forty inches. This would give it as equal to the one hundred and thirty-fifth part of an inch given in these tables.

According to Mr. Beaumont's tables there would be  $67\frac{1}{2}$  threads per inch of this yarn in a perfect cloth; according to the tables given here, if diameters and spaces are equal, there would be 54 per inch, or a difference of a little over 20 per cent.

It does not require, now, much consideration to see that the two agree as nearly as possible. If the threads are bent, and both warp and weft bent in an equal degree, the distance required between them to allow the intersecting threads to, not only touch, but to slightly press upon each other—and

also bearing in mind that linen yarn, being firmly twisted, cannot be subjected to much compression in the process of weaving—will be reduced by at least the difference, and without taking the trouble, though it would not be difficult, to illustrate the point by actual measurements, practice itself proves that this nearly approximates to truth. It may therefore be said that the deductions drawn from practical experiment, and careful observation by Mr. Beaumont, in the early part of last century and those now made, are practically agreed, and that they may be taken as being sufficiently reliable; subject, of course, to the proper amount of care and discrimination in their application to practice.

It requires before leaving this subject to notice one other authority respecting the diameters of yarns. Mr. Robert Johnstone, in his *Designers' Hand-book*, in giving a rule "To set Webs in Reed," says, "I have often been asked why the square root of the size weight of yarn, multiplied by the numbers stated in this Rule, give the number of the reed in which to set yarn. I answer the question in this way:  $-\frac{1}{9}$ th of an inch divided by the square root of any weight of yarn is equal to the diameter of it." Now if that is so, the diameter of 1's yarn will be  $\frac{1}{9}$ th of an inch. And that of 25's yarn will be  $\frac{1}{25}$ th of an inch. The yarns dealt with here are presumably the Galashiels yarns. According to the tables given here, and which are made from actual measurements, the diameters of 1's, Galashiels yarn is  $\frac{100}{11874}$  or  $\frac{1}{11874}$ , or there would be nearly 12 threads per inch, that of 25's is a little over  $\frac{1}{59}$ , so that there is a rather wide difference. Mr. Johnstone does not say how he arrived at his conclusion as to the diameters of yarns, whether from measurements or observations of cloths, but it is presumably the latter. If so, considering the fact that the class of cloths to

which he applies it, viz., woollen goods which require milling, and in which the yarn, from its very structure, can be easily compressed; and making allowance for the shrinkage in milling, which will necessarily bring the threads closer together—the latter being the most important condition which he does not seem to take into account—his rule, and the tables given here, substantially agree, or at least sufficiently near for all practical purposes. The only fault that can be found with him is that he gives the  $\frac{1}{9}$ th of an inch as the actual diameter of the thread, whereas it represents the diameter with an allowance for compression, shrinkage, and milling.

Taking it then that there is a substantial agreement between the authorities quoted, and the tables given, here as to the actual diameters of threads, definite rules may be laid down to find the number of ends and picks per inch to produce a perfect cloth with any yarn, and in any pattern.

Leaving aside then the questions of bending of the threads, compression, and shrinkage, the question of finding ends and picks required to make a cloth of any pattern, where warp and weft are equal, from a given count of yarn, may be resolved by the

RULE (44).—Multiply the diameter of the yarn by the number of ends in the pattern, and divide by the number of ends, plus the number of intersections in the pattern.

Or it may be stated in another way, thus :

RULE (45).—As the number of ends, plus intersections in the pattern, is to the number of ends, so is the diameter of the yarn to be used, to the ends or picks per inch required.

*Example 1.*—A cloth is required to be made with 30's worsted, the pattern a four end twill—west over and under two ends—how many threads per inch are required?

There being four threads and two intersections,  $4+2=6$ , the diameter of the thread is  $\frac{1}{117}$ , then

$$\text{As } 6:4::117:78;$$

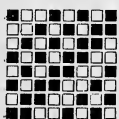
$$\text{Or } \frac{117 \times 4}{6} = 78.$$

*Example 2.*—It is required to make a woollen cloth from 20 skein (Yorkshire), the pattern is to be a six-end twill—west over and under three threads—how many ends per inch are required?

There are here six threads and two intersections, the diameter of the thread is  $\frac{1}{60}$ , then

As  $8:6::60:45$ , or  $\frac{6 \times 60}{8} = 45$ , so that 45 ends per inch are required

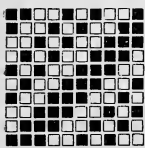
*Example 3.*—It is required to make the accompanying design with 40's cotton; how many ends per inch will be required?



Here there are 8 threads and six intersections, then  $8+6=14$ , and the diameter of 40's cotton is  $\frac{1}{165}$ , then

As  $14:8::165:94$ , or  $\frac{8 \times 165}{14} = 94$ , so that 94 ends per inch will be required.

*Example 4.*—It is required to make the accompanying design with 30's linen; how many ends per inch will be required?



Here there are ten ends and six intersections, then,  $10+6=16$ , and the diameter of a 30's linen thread is  $\frac{1}{85}$ , then

As  $16:10::85:53$ , or  $\frac{10 \times 85}{16} = 53$ , so that 53 ends per inch are required

In these examples there is no allowance for bending, compression, or room for shrinkage in milling or otherwise. If a cloth is made in which warp and weft will bend much, or where the thread may be subjected to compression, or where it is likely to lose much of its bulk in any process subsequent to the weaving, as bleaching, &c., then a greater number of threads must be employed, the increase ranging from ten to twenty per cent. according to circumstances. If on the other hand room is required to allow the cloth to mill or shrink up afterwards, then the number of threads must be reduced proportionately; this will vary according to the amount of shrinkage likely to take place.

It must be borne in mind also, that all cloths subjected to much milling or shrinking, lose some of the bulk of the individual threads by the cleansing process, therefore this must be taken into account also, or the reduction in the number will be too great. Suppose for instance that a shrinkage of 20 per cent. is to take place, that is, that the width and length of cloth will be reduced by that much in finishing, then a corresponding reduction in the number of threads per inch in the reed must be made, but if the yarn is likely to lose ten per cent. of its bulk in the cleansing processes, then a reduction of ten per cent. only will be made, because this reduction of bulk will neutralize so much of the shrinkage.

By a careful observation of these rules cloths of any kind may be made perfect without any risk or speculation.

The examples given here, of course refer to cloths in which warp and weft are equal, so that ends and picks will be equal. A slight inequality may be introduced, as the weft made a little thinner than the warp. or *vice versa*, and a corresponding

alteration made in the number of picks, but care must be taken not to carry it too far. If by the order of interweaving, as pointed out at pages 121 to 128, or the character of the cloth is to be completely altered by making a cord or rib, then it is only necessary to resort to the rules laid down for that purpose, and couple with them the diameters of threads given in these tables, and the result will be as perfect accuracy as when the two materials are equal.

#### MODIFYING INFLUENCES.

There may certainly, be modifying influences at work to interfere in some slight degree with these rules, but these are the influences and conditions which it is the duty of the manufacturer and designer to watch, and to adapt his cloth to its requirements.

For instance it may be desirable for some reason, or purpose, to make the cloth as soft and flexible as possible, then it would be necessary to reduce the number of threads, or their bulk, in a proportionate degree, so as to obtain the softness required. On the other hand, the cloth may be required firm and stiff, in that case the number of threads, or their bulk, will require to be increased. It is for the designer of the cloth, knowing the purpose to which it is to be applied, to adapt it to its requirements; and to do so only requires a proper regard to the rules laid down here, and to the nature of the cloth required, and there can be no doubt of the complete success of the cloth to meet the requirements for which it is intended.

All laws must be subject to modifying influences, none can be so rigid as to meet every circumstance of the cases; more especially where the conditions are so varied as they are in Textile Fabrics and the qualities required of them.

## FABRICS OF THE SAME STRUCTURE BUT DIFFERENT WEIGHTS.

Having now obtained a cloth of perfect structure, it may become necessary to alter the weight, either in the direction of making a heavier or lighter cloth, and retaining the same degree of perfection so as to meet the requirements of the purpose to which it is to be applied. It may be said, "Well, but if these tables of measurements are accurate, and the rules accompanying them are also accurate, there should be no difficulty in altering the weight in any degree, and yet retain the same structure." That may be so; the tables may be accurate; the rules may be accurate; yet they would not supply the readiest means of altering the weight of a cloth. They would at all times enable one to find the ends per inch for any count of yarn, or for any pattern, but they do not necessarily afford any clue to the alteration of weight in a definite degree, or proportion.

Again, suppose the modifying influences at work are such as to take the cloth somewhat from the direct application of the rules—a by no means improbable contingency, without in any degree affecting their truth or value—such for instance, as the complete alteration of the relations of warp and weft, to meet the requirements of some particular pattern, or to produce a cloth to serve some specific purpose. This cloth may be too heavy, or it may be too light, and it is required to alter the weight in a given proportion, and at the same time to preserve the exact structure of the fabric, that is, to preserve the same relations between warp, weft, pattern, and weight.

One is at first tempted to say, "well decrease the counts, or increase the ends, in the exact ratio

in which you intend to increase the weight, or *vice versa*," but very little consideration will show that to do this, will be to alter the whole character of the structure.

Suppose, for example, the counts are decreased, that means an increase of the diameter of the thread, and if the same number of threads be retained in the same space, say per inch, the relations between the diameters and the distances apart of the threads are completely altered. If, for instance, the diameters and distances in the first case were equal, in the second case the diameter becomes greater than the distance apart, not merely in the ratio of its increase, but double that, for as much as has been added to the thread is taken from the space, therefore the relations of the two are completely altered.

Now to preserve the same character of cloth, the relation of diameters and distances of threads must remain the same, therefore, if the thread is made thicker, the number per inch must be reduced.

It would now appear as if this reduction of the number of threads in the ratio of the increase of their diameters, would neutralize all efforts to obtain increased weights. So it would if the diameter of the thread increased directly as its weight, *but it increases as the square root of its weight*, and the effect of this rate of increase may be readily seen on reference to the plate at page 46, and it becomes very apparent that an increased diameter, accompanied by a proportionately decreased number of ends, will produce a heavier cloth; and on the other hand, that a decreased diameter, and a proportionately increased number of ends, will produce a lighter cloth.



Then what is the influence of this alteration of weight upon the cloth itself? If the pattern is the same, exactly the same character of structure is preserved; the same relations remain between the diameters of the threads, their distances apart, and the order of intersection in the formation of the pattern; but, as the cloth is made heavier, it is made proportionately *coarser*, and as it is made lighter it is made proportionately *finer*. That is, thicker threads and fewer of them produce heavier cloths, and thinner threads and more of them produce lighter cloths, yet the same character of structure will prevail, and apart from coarseness or fineness, weight or lightness, the cloths will present exactly the same appearance and be equally perfect. Then the practical application of this must now be considered.

HAVING A CLOTH OF GIVEN WEIGHT, TO FIND THE COUNTS OF YARN, ENDS AND PICKS PER INCH, TO PRODUCE A CLOTH OF ANY OTHER WEIGHT AND EQUAL IN STRUCTURE.

Suppose a cloth has been made, and from any cause it is found to be too heavy or too light to serve its purpose. Or further, suppose, as often happens, a cloth being made for the summer season is required for the winter season, or *vice versa*. The cloth must be made heavier or lighter as the case may be, then by the law just laid down, it will be necessary to alter the diameters of the threads, and to alter their number in the same ratio; and as the diameters vary inversely as the square root of their counts, for the first it will be by the

RULE (46).—As the weight of the required cloth is to the weight of the given cloth, so is the

square root of the counts of yarn in the given cloth, to the square root of the counts of yarn in the required cloth.

Or what is equal to that :

RULE (47).—As the weight squared of the required cloth, is to the weight squared of the given cloth, so is the counts of yarn in the given cloth, to the counts of yarn in the required cloth.

*Example.*—A cloth is made with 20's warp, and it is required to make a cloth of the same character, one-sixth heavier; what counts of warp will be required?

By the first rule:

As  $7:6::\sqrt{20}::\sqrt{x} = 14\frac{34}{9}$ , the counts required.

Or as  $7^2:6^2::20:x = 14\frac{34}{9}$ , the counts required.

Therefore the counts will be nearly 15's to give an increased weight of one sixth.

It will be observed here, as has been pointed out previously, that the cloth being increased one-sixth, the six parts of which it originally consisted become seven, therefore the proportions are as seven to six; had the cloth been made one-seventh lighter, the reverse would have been the case.

Again, it must be further observed that the counts are not given in any particular denomination, that is quite a matter of indifference, the question is one of proportion only, and applies equally to any count system, therefore in these illustrations it will be better, with the exception of a few special examples, to show their direct application; to deal with the counts in a general sense, and not to apply them to any particular material.

Having found the counts required, it will be necessary now to find the ends per inch of that count which will produce a cloth of the same character as the given cloth. On the face of it there are two matters which will render the alteration of the ends necessary. In the first place, the relations of the diameters and distances are altered, and in the second place the alteration in weight is not as 6 to 7, if the same number of ends were to be used, but as  $14\frac{3}{4}$  to 20, or in round numbers as 3 to 4.

Then again, bearing in mind the relative diameters of threads of different counts, the ends per inch or sett, will be found by the

RULE (48).—As the square root of the counts of yarn in the given cloth, is to the square root of the counts of yarn found for the required cloth, so is the ends per inch or sett of the given cloth, to the ends per inch or sett of the required cloth.

Or what is equivalent and easier in practice, because of its saving awkward fractions :

RULE (49).—As the counts of yarn in the given cloth, is to the counts of yarn in the required cloth, so is the ends per inch or sett, squared, of the given cloth, to the ends per inch or sett squared of the required cloth.

*Example.*—Suppose the given cloth in this case had 60 ends per inch ; how many ends per inch should the required cloth have ?

$$\text{As } \sqrt{20} : \sqrt{14\frac{3}{4}} :: 60 : x = 51\frac{3}{7} ;$$

$$\text{Or as } 20 : 14\frac{3}{4} :: 6^2 \times 2 = 51\frac{3}{7}.$$

It will be observed here, that the words "ends per inch, or sett," are used in the rule.

The remark which applies to the first rule applies to this: the question being simply one of proportion, it is directly applicable to any sett system, no matter what its basis.

This latter process can be considerably shortened.

It is obvious that 7 being to 6 as the  $\sqrt{20}$  is to the  $\sqrt{14\frac{3}{4}}$ , or that  $\sqrt{20}$  is to the  $\sqrt{14\frac{3}{4}}$ , as 7 is to 6, therefore it may be said with equal truth that:

7:6::60:51 $\frac{3}{7}$  is equal to

$\sqrt{20} : \sqrt{14\frac{3}{4}} :: 60 : 51\frac{3}{7}$ , and consequently to  
20:14 $\frac{3}{4}$ ::60<sup>2</sup>:X<sup>2</sup>=51 $\frac{3}{7}$ .

Such being the case, the latter portion of the working may be reduced to the

**RULE (50).**—As the required weight is to the given weight, so is the ends per inch, or sett, of the given cloth, to the ends per inch, or sett of the required cloth.

It may seem to have been unnecessary to have given the first rule here; so far as practical work is concerned, it certainly is unnecessary, but the reason for the latter rule could not have been made sufficiently clear without it, therefore it was felt better to give it.

One further example may not be out of place, for the purpose of clear illustration.

*Example 2.*—A cloth with 72 threads per inch of 40's yarn is required to be made one-fifth lighter, what counts of yarn, and how many threads per inch will be required?

If the cloth is to be one-fifth lighter, the five parts will be reduced to four, then to find counts :

As  $4^2 : 5^2 :: 40 : x = 62\frac{1}{2}$ , the counts required ;

And as  $4 : 5 :: 72 : 90$  ends per inch required.

Now to prove that this is true, suppose the above to be a cotton warp, and take the width in the reed at 30 inches, and the length of warp as 50 yards, then find the weight of a warp in each case, thus, by rule 20 :

$$\frac{72 \times 30 \times 50}{840 \times 40} = 3\frac{3}{4} \text{ lbs. as the weight}$$

of the first warp, and then

$$\frac{90 \times 30 \times 50}{840 \times 62\frac{1}{2}} = 2\frac{4}{7} \text{ lbs., and } 3\frac{3}{4} \text{ lbs. is}$$

to  $2\frac{4}{7}$  lbs. as 5 is to 4, therefore the relation of the diameters and distances of the thread have been preserved, and the weight has been reduced in exactly the proportion required.

The calculations and rules so far have direct reference to warps only, but they are equally applicable to weft, merely substitute the word weft for warp, and the application of the rules are exactly the same. So as to show this clearly, take a whole cloth : warp and weft.

*Example.*—A cloth is made with 56 ends per inch of  $2/30$ 's yarn for warp, and 60 picks per inch of single 18's yarn for weft, it is required to increase the weight one fifth.

Then  $2/30$ 's equals 15's, and an increase of one-fifth will make the total weight consist of six parts, and

As  $6^2 : 5^2 :: 15 : x = 10\frac{1}{3}$ , the counts of warp ;

And as  $6^2 : 5^2 :: 18 : x = 12\frac{1}{2}$ , the counts of weft.

And having found the counts of warp and weft, to find ends and picks per inch it will be

As  $6:5::56:\times = 46\frac{2}{3}$ , the ends of warp, and

As  $6:5::60:\times = 50$ , the picks of weft.

If the calculation be worked out for this in any yarn, or any system of counting, to find the weight of a piece of given width and length, it will be found to be exactly true. Reference to any particular class of yarn, or system, has been studiously avoided because the rules are applicable to all yarns, or to any system of counting. In fact, it is simply a question of proportion, and provided the cloth to be produced is in the same class of yarn as the cloth given, it must always apply. Rules will be given for changing from one class of yarn to another or from one system of counting to another.

HAVING A CLOTH OF GIVEN WEIGHT TO FIND THE COUNTS OF YARN, ENDS AND PICKS PER INCH, TO PRODUCE A CLOTH OF ANY OTHER PATTERN AND WEIGHT, AND EQUAL IN STRUCTURE.

This differs from the question just dealt with in one respect only, and that is in respect to the alteration of the pattern. The simplest mode of dealing with it would appear to be to find counts and ends or picks per inch by the rules just laid down, for the same pattern as the given cloth, and then by rule 36, find what alteration in the ends and picks will be required. But there is obviously one difficulty to be encountered; when the counts and ends or picks have been found for the same pattern as the given cloth, they would give the required weight in that pattern, but the change of pattern will alter the weight, because if there are fewer intersections, more threads will be required,

and *vice versa*, therefore the mere alteration in pattern will make an alteration in weight, and consequently a fresh calculation would have to be gone through to bring it back to the proper weight, which would necessarily be of the same character as the first calculation of weights, or in other words, the alteration of pattern may either neutralize or intensify the first alteration of counts, ends per inch, &c.

Suppose for example, a cloth has been made of four-end twill (weft passing over and under two ends), it contains 60 ends per inch of 20's yarn, of any material, and the same number of picks of the same counts; it is required to change to a six-end twill (weft passing over and under three ends), what counts of yarn, and what number of ends and picks will be required, to increase the weight one-eighth.

By the rules just laid down as to the counts and weight it would be necessary to find the counts and threads per inch for the same pattern.

Thus:  $9^2 : 8^2 :: 20 : x = 15\frac{5}{8}$ , and

As  $9:8::60:x = 53\frac{1}{3}$ ; that gives the increased weight for the same pattern, but to change the pattern by rule 36. In the one case, there are four ends and two intersections, and in the other there are six threads and two intersections, therefore

$$\frac{6 \times (4+2) \times 53\frac{1}{3}}{4 \times (6+2)} = 60$$

$$\text{Or } \frac{6 \times 6 \times 53\frac{1}{3}}{4 \times 8} = 60.$$

Or further reduced or simplified :

As  $8:9::53\frac{1}{3}:60$ .

Now this increased number of threads will give a considerably increased weight; then the weight would have to be brought back again in the proper

proportion, an operation which would involve a considerable amount of labour.

Such being the case it will be better to use the number of ends and intersections in each pattern as direct factors, and reduce the working to one of compound proportion. Then to find the counts the following will be the

RULE (51).—As the required weight squared, is to the given weight squared, and as the ends plus intersections in the given pattern is to the ends plus intersections in the required pattern, so is the given counts to the required counts.

And having found the counts, to find the ends and picks, proceed by the

RULE (52).—As the required weight is to the given weight, and as the ends plus intersections in the given pattern is to the ends plus intersections in the required pattern, so is the ends per inch in the given cloth to the ends per inch in the required cloth.

To work out the example given, it will be

As  $9^2 : 8^2$ ,

And as  $6 : 8 :: 20 : 21\frac{17}{243}$ , which will be the counts of warp required, and to find the ends per inch :

As  $9 : 8$ ,

And as  $6 : 8 :: 60 : 71\frac{1}{9}$ , the number of ends per inch required.

Or in the shape of formulæ, to find counts :

$$\frac{8 \times 8 \times 8 \times 20}{9 \times 9 \times 6} = 21\frac{17}{243}$$

$$\text{And to find ends } \frac{8 \times 8 \times 60}{9 \times 6} = 71\frac{1}{9}$$



The same rules apply equally to warp and weft, and, as in the previous case, the question being one of proportion only, the rules are equally applicable to any material, to any system of counting, or to any sett system.

HAVING A CLOTH OF GIVEN WEIGHT TO FIND THE COUNTS OF YARN, ENDS AND PICKS PER INCH, TO PRODUCE A CLOTH OF ANY OTHER WEIGHT, AND TO ALTER THE CHARACTER OF THE CLOTH, AND BE EQUALLY PERFECT IN STRUCTURE.

To accomplish this, the mode of procedure differs from either of the questions just dealt with, in one respect, that the relations of warp and weft must be altered. After what has been said upon this subject previously, it will scarcely be necessary to dwell at any length upon the matter here, the chief considerations are simply these:—The increased or decreased bulk of the threads must be found by the rules just laid down, then the further consideration of an increase in the bulk and decreased number of one set of threads, and a corresponding decrease in bulk, and increase in numbers of the other set of threads of which the cloth is composed must be dealt with on the principles laid down at pages 121 to 128.

There are so many considerations involved in this alteration of the relative quantities; the character of the pattern, and the degree of alteration required, &c., that the question can only be finally determined by a full consideration of the circumstances attending each case; that, were a fixed rule laid down, it might meet the exact requirements of one case, or of one class of cases, but it could never be sufficiently elastic to meet all cases. The rules already laid down are sufficiently complete, having

a proper regard to their application, to meet all requirements; but in such cases as suggested here, they will require an intelligent interpretation, as well as care and discrimination in their use; that given, they will be found to serve all their purposes.

It now remains to give a few applications of the general rules laid down, for the purpose of making the subject still clearer, and so that in their various forms they may be handy for reference.

TO CHANGE FROM ONE COUNT TO ANOTHER COUNT AND TO FIND SETT OR PICKS TO RETAIN THE SAME CHARACTER OF CLOTH.

This is simply a slight variation of the rule for altering the weight of a cloth, or more correctly speaking, a part of it, and is resolved by the

RULE (53).—As the square root of the given count is to the square root of the required count, so is the given sett, ends per inch, or picks to the required sett, ends per inch, or picks per inch.

RULE (54).—Or, as the given count is to the required count, so is the sett, ends per inch, or picks per inch of the given cloth squared, to the sett, ends per inch, or picks per inch of the required cloth, squared.

*Example.*—It is required to change from 40's yarn in a 60 sett, to 60's yarn. What sett will be required?

$$\text{As } \sqrt{40} : \sqrt{60} :: 60 : x = 73\frac{1}{2};$$

$$\text{Or as } 40 : 60 :: 60^2 : x^2 = 73\frac{1}{2}.$$

And so for any counts, material, or sett system, and of course equally for picks.

The next variation is

TO CHANGE FROM ONE SETT OR PICKS PER INCH, WITH A GIVEN COUNT OF YARN, TO ANOTHER SETT OR PICKS PER INCH, AND FIND WHAT COUNTS OF YARN WILL BE REQUIRED.

This is simply a variation of that just given, instead of counts being given to find sett or picks, the sett or picks are given to find counts, and will be determined by the

RULE (55).—As the sett or picks of the given cloth is to the sett or picks of the required cloth, so is the square root of the count of the given cloth, to the square root of the count of the required cloth. Or

RULE (56).—As the sett or picks of the given cloth squared, is to the sett or picks of the required cloth squared, so is the counts of the given cloth to the counts of the required cloth.

*Example.*—A cloth is made with 40's yarn in a 60 sett, it is required to make a similar cloth in 80 sett, what counts of yarn will be required.

$$\text{As } 60 : 80 :: \sqrt{40} : \sqrt{x} = 71\frac{1}{9};$$

Or as  $60^2 : 80^2 :: 40 : x = 71\frac{1}{9}$ ; so that  $71\frac{1}{9}$  is the counts required.

It sometimes may occur that a cloth made in one material may be required to be produced in

another material, say for instance, a linen cloth in cotton, or *vice versa*, or a worsted cloth in woollen, or from any one material to another ; in such case if the diameters of the threads of the different materials, for similar weights of yarn are the same, then it may be reduced to a simple rule. If the diameters are different for similar weights of yarn, then the difference would have to be taken into account, but that would simply mean that their relative diameters would be taken into account as factors in the proportion, and would therefore cause a slight increase, or decrease, as the case might be.

This question may assume two forms, first, when the setts in which the two fabrics must be made is known, and it is required to find the counts of yarn for the second one ; and, second, when the counts of yarn to be used in the two fabrics is known, and it is required to find the sett or picks of the second one. Then for the first condition :

TO FIND WHAT COUNTS OF ONE MATERIAL MAY BE SUBSTITUTED FOR ANOTHER MATERIAL OF GIVEN COUNTS—AS WOOLLEN FOR WORSTED, WORSTED FOR COTTON, &c.,—TO PRODUCE A SIMILAR CLOTH, WHEN THE SETT OR PICKS OF THE TWO FABRICS IS KNOWN.

In the first place, in the majority of instances, the two materials would be calculated on different bases, therefore in some manner they must be reduced to the same value, this may be done either before commencing to find the required counts, or it may be embodied in the same formula, in the first case, it would simply mean a resort to

rule 1, which would provide the answer, or in the second case it will be obtained by the

**RULE (57).**—As the sett of the given cloth is to the sett of the required cloth, so is the square root of the given counts, multiplied by the yards per hank, or skein, upon which the counts system is based, and divided by the yards per hank, or skein, upon which the counts system of the required yarn is based, to the square root of the required counts. Or

**RULE (58).**—As the sett of the given cloth squared is to the sett of the required cloth squared, so is the given counts, multiplied by the yards per hank, or skein, upon which its counts system is based, and divided by the yards per hank or skein, upon which the counts system of the required yarn is based, to the required counts.

*Example.*—It is required to make a cloth in woollen, similar to a given cloth in worsted, the worsted is in a 60 sett, counts of yarn  $2/30$ 's, the woollen must be in 40 sett; what counts of woollen will be required?

The worsted counts is based upon 560 yards, and the woollen upon 256 yards per lb.

$$\text{As } 60:40:: \sqrt{\left(\frac{2/30 \times 560}{256}\right)} : \sqrt{\times} = 14\frac{5}{9};$$

Or by the alternative rule, and which is the easiest in practice:

$$\text{As } 60^2:40^2:: \left(\frac{2/30 \times 560}{256}\right) : \times = 14\frac{5}{9}.$$

This, of course, is only a variation in form of the rule already given for finding counts, for it is in effect reducing the worsted yarn to woollen denomination, that being done by simply applying the rule No. 1; but it has this advantage in stating the question, that all the terms of which it is composed are present in the statement, and therefore it is easy to see whether it has been mis-stated or not, otherwise it possesses no advantage.

Then for the first case :

TO FIND WHAT SETT OR PICKS PER INCH WILL BE REQUIRED TO PRODUCE A CLOTH OF ONE MATERIAL, SIMILAR TO A GIVEN CLOTH OF ANOTHER MATERIAL, THE COUNTS IN EACH CASE BEING KNOWN.

This is simply a reversal of the rule given above, and will be determined by the

RULE (59).—As the square root of the counts of the given yarn, multiplied by its yards per hank, or skein, is to the square root of the counts of yarn for the required cloth, multiplied by its yards per hank, or skein, so is the given sett to the required sett. Or

RULE (60).—As the counts of the yarn of the given cloth, multiplied by its yards per hank or skein, is to the counts of the yarn for the required cloth, multiplied by its yards per hank or skein, so is the given sett or picks squared, to the required sett or picks squared.

*Example 1.*—A worsted cloth is made with 2/30's warp and 64 ends per inch, it is required to produce a similar cloth in woollen, the counts of yarn to be 18 skein (Yorkshire count), how many threads per inch should be used? Then

$$\text{As } \sqrt{(2/30's \times 560)} : \sqrt{(18 \times 256)} :: 64 : x = 47\frac{2}{5}$$

$$\text{Or as } (2/30 \times 560) : (18 \times 256) :: 64^2 : x^2 = 47\frac{2}{5}.$$

So that 47 $\frac{2}{5}$  ends per inch of woollen will produce a cloth exactly similar in character to one made with 64 threads per inch of 2/30's worsted.

In changing from any one material to any other, as from worsted to cotton, from woollen to cotton, or in any direction substitute the yards per hank, or whatever may be the basis of the counts system in the two materials for those given here, because by multiplying the counts by yards per hank, &c., in each material, the relative length of each is at once shown for a given weight, and consequently their diameters will be to each other as the square roots of their relative lengths.

*Example 2.*—It is required to make a cloth with 2/60's cotton, similar to a cloth made from 2/50's worsted, the worsted cloth has 72 ends per inch, how many will the cotton cloth require?

$$\text{As } \sqrt{(2/50 \times 560)} : \sqrt{(2/60's \times 840)} :: 72 : x = 96.6 \text{ nearly ;}$$

$$\text{Or as } (2/50 \times 560) : (2/60 \times 840) :: 72^2 : x^2 = 96.6 \text{ nearly.}$$

So that 96.6 ends per inch of 2/60's cotton will produce a cloth exactly similar in character, to one made with 72 ends per inch of 2/50's worsted, that is, the number of threads per inch in each case, bears the same relation to the diameter of the thread.

Of course everything that has been said of warp in all these examples, applies equally to weft, the word weft might have been substituted for warp all the way through, or the two might have been combined.

#### TO ALTER CLOTHS IN WEIGHT ONLY.

When cloths are altered in weight, they must of necessity be altered in both the counts of the warp and weft of which they are composed, and also in the number of threads per inch of both weft and warp, if the character of structure is to remain the same, therefore any alteration of weight, and retaining the same relation between weft and warp, and between the diameters of threads, and their distances apart, must of necessity make the cloth coarser, if more weight is obtained, and consequently finer if less weight is obtained, but despite this coarseness and fineness, the characteristic features of the cloth must remain the same; then the question of altering weight only cannot be admitted, for either there must be an alteration in the degrees of coarseness and fineness which the cloth presents, or an alteration in the relation of warp to weft, or of pattern, or no alteration in weight can take place; then in speaking of the alteration of the weight of a cloth, one of those conditions must of necessity come in; undoubtedly the best method of altering weight is by the rules laid down here, when the same character of cloth is maintained.

#### TO ALTER CLOTHS IN FINENESS OR COARSENESS ONLY.

Following immediately upon what has been said, it is very evident that cloths cannot be altered in one direction only. It is necessary to



make this quite clear, for it is quite a common thing for a buyer to say, "I want exactly the same thing, but a little finer,"—now that is an impossibility. If made either finer or coarser, either the weight must be altered, or the character of the cloth must undergo some change. Possibly the latter alternative is in many cases the best for the alteration in the character of the cloth may be slight, it may give an appearance of greater fineness, and yet not alter the weight in any material degree, but it must of necessity arise from an alteration of the relations of warp and weft, or of the pattern; the former is in a great majority of cases the best, for not only may it not be detrimental to the fabric, but it may be decidedly advantageous. In one direction it will be decidedly so, that is if increased fineness is obtained, and the weight maintained, for then the alteration in the direction of fineness will be in one direction only, either weft or warp, and the cloth will of necessity be more close and compact, and therefore a warmer article of clothing.

TO ALTER CLOTHS IN RESPECT TO BOTH FINENESS  
AND WEIGHT.

As already pointed out, when a cloth is altered in weight, and regard is paid to structure, then it becomes finer or coarser as the weight is reduced or increased, but to obtain both increased weight and fineness at the same time, is a most difficult matter. As in the other cases just dealt with, it can only be obtained by altering the relations of warp and weft, or pattern; the latter is the easiest mode of obtaining it, but the former will give the best results when carefully carried out. To obtain this result, one of the sets of threads—either weft or warp—must be very much increased in thickness,

and proportionately—or rather more than proportionately—reduced in quantity, so as to give a greater space between each thread, then the bulk of the weft must be reduced, and the number of picks very much increased. The increased space between the warp will permit of a greater number of picks of weft being inserted, therefore weight is obtained in both directions, and fineness is obtained by the close compactness of the weft, and the coarse warp being thoroughly covered and hid from sight. Of course the conditions may be reversed, and the warp made the finer yarn, and in either case good results may be obtained, but care must be taken not to carry the difference between the two sets of threads too far, without proper regard to the order of interweaving, or the result cannot be satisfactory, and this of course indicates that there is a limit to which increased weight and fineness combined can be carried without alteration of the pattern, and probably then, the alteration of pattern would to some extent neutralize the increased fineness obtained.



## SUMMARY.

It only remains now to briefly summarise the uses and purposes of Textile Calculations. What has hitherto been considered their chief use is the determining by means of the various systems of counting yarns, and what are known as sett systems, &c., the quantity of material which a piece of cloth contained, and the cost of such cloth, or to put it briefly, that matter which is contained in the first section of this book. For this purpose, as a perusal of that section will readily show, a great many rules have been necessary, but the greatest difficulty has been the great variety of systems in use; and the difficulty of those engaged in one district understanding the terms and mode of calculations used in another district; yet the questions of quantity and cost were the principal ones, and all others, however remote they might appear to be, necessarily led up to those two. Now these are sufficiently important objects in themselves, but the calculations in the second section of the work, where they all bear directly upon the question of the structure of the fabric are of quite as much importance. The object and aim of those rules may be briefly summarised under the heads of the alteration of cloths in weight, and retaining the same character of structure, or in alterations in regard to weight, fineness, coarseness, or pattern, with a proper regard to perfection of structure. These objects are of course preceded by the proper consideration of the proper structure of fabrics, the object of which is to ensure perfection, as far as it can be ensured by fixed rules, without leaving anything to chance or accident, and a proper regard for those rules will certainly tend to the attainment of that end.

## APPENDIX A.

## CLOTH STRUCTURE.

*Revised and reprinted from the "Textile Educator."*

The following are the results of further observations made after the publication of the second edition of this work, and published in the "Textile Educator," from which they have now been abstracted and revised.

The first point to notice is what appears to be a very curious coincidence, but which is simply the result of a deduction from the tables at pages 138 to 143, viz:—That the square root of the yards per lb. is equal to the number of threads which, laid side by side, would cover one inch, subject to a compression of ten per cent., therefore for the purpose of making calculations for a cloth this basis may be taken, and thus avoid the necessity of adding the percentage after the calculation is complete.

One thing must be distinctly understood here, the number of threads found by this process for a cloth is that which the cloth must contain in the finished state, and not the number per inch in the reed. Let us thoroughly master this branch of the subject before going further. It has just been said that the square root of the yards per lb. will give the diameter of the yarn or the number of the threads which will cover one inch. There is apparently nothing to account for this but it is simply a deduction from the tables published in my "Treatise on Textile Calculations," but some reference will be made to this subject again. It

will be as well to explain more fully the working of this system. Suppose a cloth is to be made from 40's worsted yarn, and it is desired to ascertain the number of threads per inch which should be introduced, it will be necessary to first ascertain the diameter of the thread. This will be done as follows:—There are 40 hanks per lb., each hank containing 560 yards. There would therefore be  $40 \times 560 = 22,400$  yards per lb. Now extract the square root of 22,400, thus;

$$\begin{array}{r}
 22,400 \text{ ( } 149 \\
 \text{I} \\
 \hline
 24 \text{ ) } 124 \\
 \quad 4 \quad 96 \\
 \hline
 289 \mid 2800 \\
 \quad \quad \mid 2601 \\
 \hline
 \quad \quad \quad 199
 \end{array}$$

or representing the square root of that number as a fraction it would give the diameter of the thread  $\frac{1}{149}$ th or nearly  $\frac{1}{150}$ th of an inch. On referring to my tables the diameter of 40's worsted is given as  $\frac{1}{135}$ . Take 10 per cent. from  $150 = 135$ , and the answer will be 135. As a further illustration take 30's yarn and the diameter will be found thus:— $560 \times 30 = 16800$ , and the square root of 16800 is

$$\begin{array}{r}
 16800 \text{ ( } 129 \text{ Nearly } 130. \\
 \text{I} \\
 \hline
 22 \mid 68 \\
 \quad 2 \mid 44 \\
 \hline
 249 \mid 2400 \\
 \quad \quad \mid 2241 \\
 \hline
 \quad \quad \quad 159
 \end{array}$$

then deduct 10 per cent. from 130 and it will be  $130 - 13 = 117$ , exactly as in my table.

The same rule applies to cotton and to all other yarns where the basis of the calculation is of a similar character, that is, where it is resting upon the number of hanks or skeins per lb., and the higher the counts the finer the thread. In other systems, such as those where the higher the counts the heavier the yarn the rule would assume a different form, yet it would resolve itself into finding the number of yards per lb., and in that respect the rule will be common to all. Take one illustration of cotton yarns, and it will be found to work out in the same way. Say 80's cotton.  $80 \times 840 = 67200$ , and the square root of that number is

$$\begin{array}{r}
 67200 \text{ ( } 259 \\
 \underline{4} \\
 45 \mid 272 \\
 \underline{5 \mid 225} \\
 508 \mid 4700 \\
 \underline{\quad \mid 4572} \\
 128
 \end{array}$$

and 10 per cent. from 259 = 26 nearly.  $259 - 26 = 233$ , and the table gives 234.

It has been shown that the diameters of yarns vary as the square roots of their counts, and if these numbers be analysed it will be found that they vary in that ratio. In fact this must be so, because the count is made always a constant factor, and the number of yards per hank also. Therefore if the square root of these be taken the result must of necessity vary in the ratio of the square root of the counts, so that there is really

nothing very wonderful in the manner in which this works out beyond the fact that the square root of the yards per hank gives a number equal to the fractional part of an inch, which represents the diameter of a thread containing one hank per lb. Thus the square root of 560 is

$$\begin{array}{r} 560 (23\cdot7 \\ 4 \\ \hline 43 ) 160 \\ 129 \\ \hline 31 \end{array}$$

and 10 per cent. of 23·7 is 2·4 nearly. Then  $23\cdot7 - 2\cdot4 = 21\cdot3$ , the diameter of 1's yarn as found by actual measurement.

A deduction of this kind can of course be easily made, once the actual measurements are known. Suppose, for instance, the diameter of 1's worsted had been found to be  $\frac{1}{30}$ th part of an inch, and it was desired to find a rule which would enable us to find the diameter of any other yarn, it might be done by using the 30th as a standard number, and multiply the square root of the counts by that. To prove that this is true, it is found by actual measurement that the diameter of 1's worsted is  $\frac{1}{21\cdot3}$  of an inch, or treat it as 21·3 simply; and the square root of 60 is 7·75. Then  $21\cdot3 \times 7\cdot75 = 165\cdot176$ , or exactly as in the tables. Again the square root of 64 is 8, and  $21\cdot3 \times 8 = 170\cdot4$ . Therefore the diameter of 64's would be  $\frac{1}{170\cdot4}$ , and so of necessity for any other number, and in any material; the one thing is to first know the actual diameter of any one yarn and make the deductions upon the basis of that known yarn.

The next point to determine is whether there is anything further which can be said to strengthen

the position taken up with regard to the diameters of threads, and if a scientific base can be found for it. The following letter appeared in the "Textile Educator," and with what follows, may be taken as tending to a solution of the difficulty.

To the Editor of "*The Textile Educator*."

22nd February, 1889.

In your articles on Textile Calculations you say "that the counts of yarns represent their solidities," which of course they do.

You also say that "they may be taken to represent the areas of the threads," but you do not say why. Of course this is, that if the number represents the length of a given weight or of a given bulk, it follows that the bulk divided by the length must give the area of the cross section. It is necessary to understand this for what follows. You give the rule, "that the  $\sqrt{\quad}$  of the number of yards to 1lb. gives the diameter of the thread, or the number of threads that would lie side by side on 1in. You say, "that there is apparently nothing to account for this." Now surely, if it is correct, there must be a reason for it, and that it is, at least fairly correct, there is no doubt.

I think the following rule is in the right direction, but whether quite correct or not I must leave to the able writer of these articles to determine.

Take for simplicity, 1 lea linen yarn 300 yards to 1lb. and take the sp. gr. at 1.50.

There are 18.48 cubic inches of solid matter in 1lb.; suppose this to be a gummy matter such as the spiders and silk worms use, and that it is drawn out to 300 yards. Now  $\frac{18.48}{300 \times 36} = .00017$ , and

$\frac{.00017}{.7854} = .0002165$ , and  $\sqrt{.0002165} = .0147 =$  the diameter of the yarn.



For 1 lea linen yarn your rule gives  $\frac{1}{17}$  of an inch, which shows a wide difference, but it is easily accounted for, as yarn is not in the state of density indicated by the sp. gr. of the matter of which it is composed; at 1.50 it would be more solid than coal. To test the rule I got a piece of copper wire which had 17.36 yards to 1 lb., and the diameter was  $\frac{1}{32}$  of in. or there were 12 diameters in  $\frac{3}{8}$  in. The sp. gr. is 8.92, and the solid contents would be 3.108.

Take this as 1 lea yarn, with 17.36 yards to 1 hank or lea, then,  $\frac{3.108}{17.36 \times 3} = .0049$ , and  $\frac{.0049}{.7854} = .0063$ , and  $\sqrt{.0063} =$  nearly  $\frac{8}{100}$  or  $\frac{1}{12}$ .

To arrive at a correct result in yarn it would be necessary to know the sp. gr. of the yarn in the state of density under which the measurements were made. Working backwards from your rule, I found that it was somewhat lighter than water, say 28.27 cubic inches to 1 lb.

Now 300 yards  $\times$  diam.<sup>2</sup>  $\times$  .7854 = lb. (linen scale), and  $300 \times D^2 \times .7854 \times 27.72 =$  the cubic inches of water in 1 lb.; then  $D^2 = \frac{27.72}{300 \text{ yds.} \times .7854}$  or bring to inches, and  $D^2 = \frac{27.72}{300 \times 36 \times .7854}$  and  $(36 \times .7854 = 28.27) \frac{28.27}{300 \times 28.27} = \frac{1}{300}$ , or 300 on which to perform your calculations, viz:—extract  $\sqrt{\quad}$  of 300 for number of threads in one inch.

B. T. F.

I must, before continuing, acknowledge the letter by B. T. F., and at once set to work to explain it. In the first place he calls attention to an omission in speaking of the areas of threads; the words should be "sectional area." or the area represented by a cross-section of the thread; and, in speaking of the method adopted for finding the

diameter of the yarns, viz., by extracting the square root of the yards per lb., he calls attention to the expression "that there is apparently nothing to account for this," and goes on to say "Now, surely, if it is correct, there must be a reason for it," and at once admits that it is "fairly correct," that there is a reason there can be no doubt, and there is equally little doubt that B. T. F. has struck at the true principles which underlie it, but, as I have not been thoroughly satisfied in my own mind upon the data, I have refrained from publishing anything relating to it until I could satisfy myself thoroughly as to the reasons. I will endeavour to make it clear that the expression that "there is apparently nothing to account for it" is well advised, because there will have to be something assumed, which cannot be said to be capable of absolute demonstration. B. T. F. then proceeds to give a method of working to find the diameter of a thread, which undoubtedly is the true basis, and, in doing so, he commences with the specific gravity of fibres, that of vegetable fibres being given by Dr. Ure at 1.5.

I will first give a full explanation of B. T. F.'s working and its reasons, so that I may deal with one important question which he raises, that is, "the specific gravity of the yarn in the state of density under which the measurements were made."

He first proceeds to find the number of cubic inches of solid matter in one lb. of fibre with a specific gravity of 1.5, and gives the number of cubic inches of water in one lb. at 27.72. I am not quite sure whether it should not be 27.64, but will accept his figures. For those not familiar with the subject, it may be useful to state the specific gravity is the ratio of the bulk of the substances in question, and a standard substance,

and that standard substance is a cubic foot of pure water which at a temperature of  $60^{\circ}$  weighs 1,000 ounces avoirdupois, so that anyone may work it out for himself. Then, the specific gravity of vegetable fibre being  $1.5, \frac{27.72}{1.5} = 18.48$  cubic inches of solid matter in one lb. The next operation is to find the sectional area of a thread drawn from this bulk to a given length, and to reduce it to the convenient unit of one inch, therefore, as there are 300 yards per lea in linen, and 36 inches per yard, it would be  $\frac{18.48}{300 \times 36} = .0017$ , so that would represent the sectional area of this thread drawn out to 300 yards, and it must be remembered that the thread would be one solid, compact mass.

Now a thread represents a cylinder, and the rule for finding the area of the base of a cylinder is to multiply the square of the diameter by .7854, but, as the area is already found, and the diameter is required, this must be reversed, hence the area divided by .7854, will give the diameter squared, so that the square root of the quotient must be extracted to find the diameter, then  $\frac{.0017}{.7854} = .002165$ , and the square root of  $.002165 = .0465$ , or  $\frac{10,000}{465} = 25.8$ , so that 25.8 threads would lie side by side. (There is, apparently, an error in B. T. F.'s figures, but I have refrained from correcting them.) As B. T. F. points out, there is a wide difference between this number and that obtained by extracting the square root of yards per lb., which for 1's would be  $\sqrt{300} = 17.32$ , or, as given in my tables, 15.5.

Now it must be quite clear that when this is looked at, and the different results compared, "there is no apparent reason" for obtaining the diameters by extracting the square root of the

yards per lb., and my tables of diameters, obtained by actual measurements, may be called in question, and with very good reason too, because, it is quite clear, and is demonstrated by B. T. F., that for solid bodies, such as copper, the method under consideration holds good. Then let us see what are the conditions which affect this method, and influence and determination of the diameters of threads.

It has already been pointed out that threads with different degrees of twist may vary much in their diameter, and that the tables were based upon yarns with the ordinary number of turns put into yarn spun according to the empirical rules commonly in use, and also that measurements were made of hard and soft spun threads respectively, and a mean between the two taken. Therefore it is perfectly easy to understand that even in the hardest spun thread used for manufacturing purposes the fibres would not be compressed to anything like that condition which would be represented by the smallest space they could possibly occupy; or that which would represent their condition when determining their specific gravity. And even if they could be reduced to that condition they would be totally unsuitable for fabrics, as instead of a flexible material we should have one of a solid and rigid character; therefore we must determine what is the margin between what might be termed absolute compression, and that flexible condition suitable for the production of fabrics. For this purpose we may compare the three several diameters as found by the different methods of 1's linen.

As just shown, working by specific gravity there would be 25.8 threads per inch, by square root of yards per lb. 17.32, or 17, for convenience, and by

measurement 15.5. Now let us find the specific gravity "in the state of density of the threads" at each of the two latter periods. Working from the basis of 17 threads per inch, first reduce that to a decimal fraction, thus  $\frac{1}{17} = .059$ , and  $.059^2 = .003481$ . Now multiply this by .7854, thus:  $.003481 \times .7854 = .0027339774$ , and that multiplied by 10800 ( $300 \times 36$ ) = 29.5269, or nearly 29.527; that is, there would be 29.527 cubic inches of matter in a more or less solid state in 1 lb. Now this is less than the weight of water; therefore we must see what would be the specific gravity of the thread in this condition and bulk, thus  $\frac{27.72}{29.5269} = .938$ , thus leaving considerable margin for further compression. Now take the diameters as found by measurement, viz: 15.5, and reduce that to a decimal thus:  $\frac{15.5}{1,000} = .0155$ , and  $.0155^2 = .00024025$ . Then  $.00024025 \times .7854 = .000188706$ , &c., which multiplied by 10800 ( $300 \times 36$ ) = 2.038, or there would be that number of cubic inches in 1 lb. This is therefore lighter than water, and would stand in relation to it  $\frac{27.72}{35.288} = .785$  about, or in round numbers one-half the real specific gravity of the fibres, so that there is the margin between the specific gravity and one half, for retaining the flexibility required in the cloth.

Now see how this will apply to worsted yarns, first taking the specific gravity at 1.5, and the cubic inches of water in the 1 lb. at 27.64. There would then be  $\frac{27.64}{1.5} = 18.43$  cubic inches of solid matter in 1 lb. Now draw this solid matter out into a cylinder of the length of one hank of worsted, and find the sectional area thus:  $\frac{18.43}{560 \times 36} = .000914$ . Then to find the diameter  $\frac{.000914}{.7854} = .001164$ , and the square root of .001164 = .0341 or reduced to the

number which would lie side by side in one inch  $\frac{10,000}{.0341} = 29.32$ , in the state of density represented by the specific gravity.

If the specific gravity of the wool be taken at 1.33, then it would be  $\frac{77.64}{1.33} = 20.7$ , and  $\frac{20.7}{560 \times 36} = .001030$ , and  $\frac{.001030}{.7854} = .001311$ , the square root of which is .0362, or reduced to the number per inch  $\frac{10,000}{.0362} = 27.62$ .

The diameter of 1's worsted is given at  $\frac{1}{21.33}$  then reduced to a decimal  $\frac{1000}{2133} = .0469$ , and  $.0469^2 = .00219961$ . And  $.00219961 \times .7854 = .001727573694$  and by  $560 \times 36 = 34.836$ . Now find the specific gravity in this condition,  $\frac{.2764}{34.836} = 79$ , or about half its full density.

#### ANGLE OF CURVATURE.

What is meant by the angle of curvature of the threads in a cloth? Not only is that the question which must be approached and discussed now, but the further question of whether there is one particular angle which will give better results than another.

I am most desirous that these questions shall be discussed in the most open manner possible. And knowing that I am upon ground which is new, I enter the field with all the consciousness of the difficulties I have to overcome, as well as prejudices to meet. What is meant by the angle of curvature of threads? Let anyone take a cloth and draw a thread of warp or weft from it and see what appearance it presents, and he will find that it is wavy; that the weft has been bent round the warp, and the warp round the weft in some degree. In different cloths this bending varies; sometimes more in the weft than the warp, and sometimes in an equal degree in both.

Well! what has this to do with the building of a cloth? The question is more easily asked than answered. I propose to make an effort to answer it, and to show that in all cloths there is a fixed angle of curvature which must be obtained either in one or both of the materials of which the cloth is composed, and that in the knowledge of this angle of curvature, and the actual diameters of threads, the whole secret of cloth building lies.

Approach the subject broadly, and I expect to be met with the questions: how about thick weft and fine warp in a cloth? How about fine weft and thick warp? and other questions relating to the difference in patterns and so forth.

Some of those questions have already been anticipated in the lessons which have already been given, and I will try to meet the others and demonstrate how they may be met, and give proof from actual cloths of the truth of the propositions I shall lay down.

Let us see for a moment what is meant by bending of warp, or weft, or both. Weave a plain cloth with warp and weft of the same material and the same counts, and let there be the same number of threads per inch in each direction. The bending powers of each will be equal. Now double the diameter of one, and alter the number per inch to suit it, and see what relations exist between the two so far as bending powers go. They will not be as they were before, nor in the ratio of their diameters, but as the *cubes of their diameters*. Therefore all the bending would practically take place in one set of threads only, and not in both.

This again has only apparently a slight significance, but in reality it has a very material one, for in any cloth it would completely alter the

relations of the two materials to each other ; and that alteration would not be in the ratio of their diameters ; but as it would affect the angle of bending of one thread round the other. This angle of bending must be of a definite quality, and no other will do ; and that this is so I will endeavour to demonstrate by means of photographs from cloths and threads, as well as by reference to well-known laws in optics.

It is quite possible that exception may be taken to some of the examples I propose to give, but every care will be taken that they will be well authenticated, and if possible—and it will be the case in most instances—the cloths will be selected from those on sale in warehouses. At any rate, no cloth will be illustrated which has been made specially for the purpose, unless the fact is made known at the time.

It is necessary now to consider the influence of threads upon each other in the formation of a cloth so as to determine how in their interlacing one set bends another, and what degree of bending should take place. At the commencement let a perfect plain cloth be the subject of consideration, and the warp and weft both of the same bulk and of the same material. Whilst the warp is held tight in the loom in the process of weaving there can be no bend or curvature given to the threads, but when taken out of the loom, whether the material be cotton, wool, silk, or any other, the strength of the weft threads will assert themselves and a waviness will appear in the warp equal to that of the weft, and if subjected to any process of washing or finishing where no strain or tension is put upon either one or the other set of threads, this bending will become more marked, and will still be the same in both warp and weft.





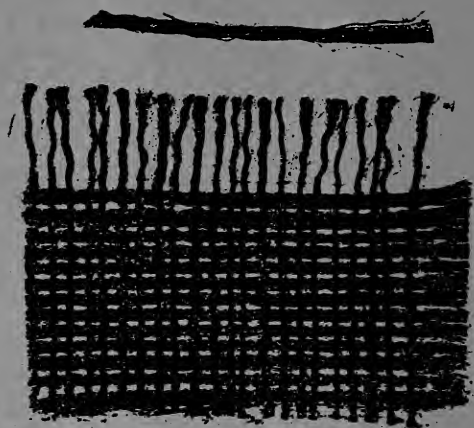


FIG. 1.

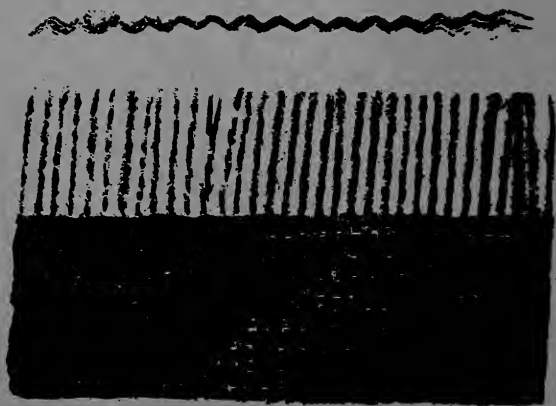
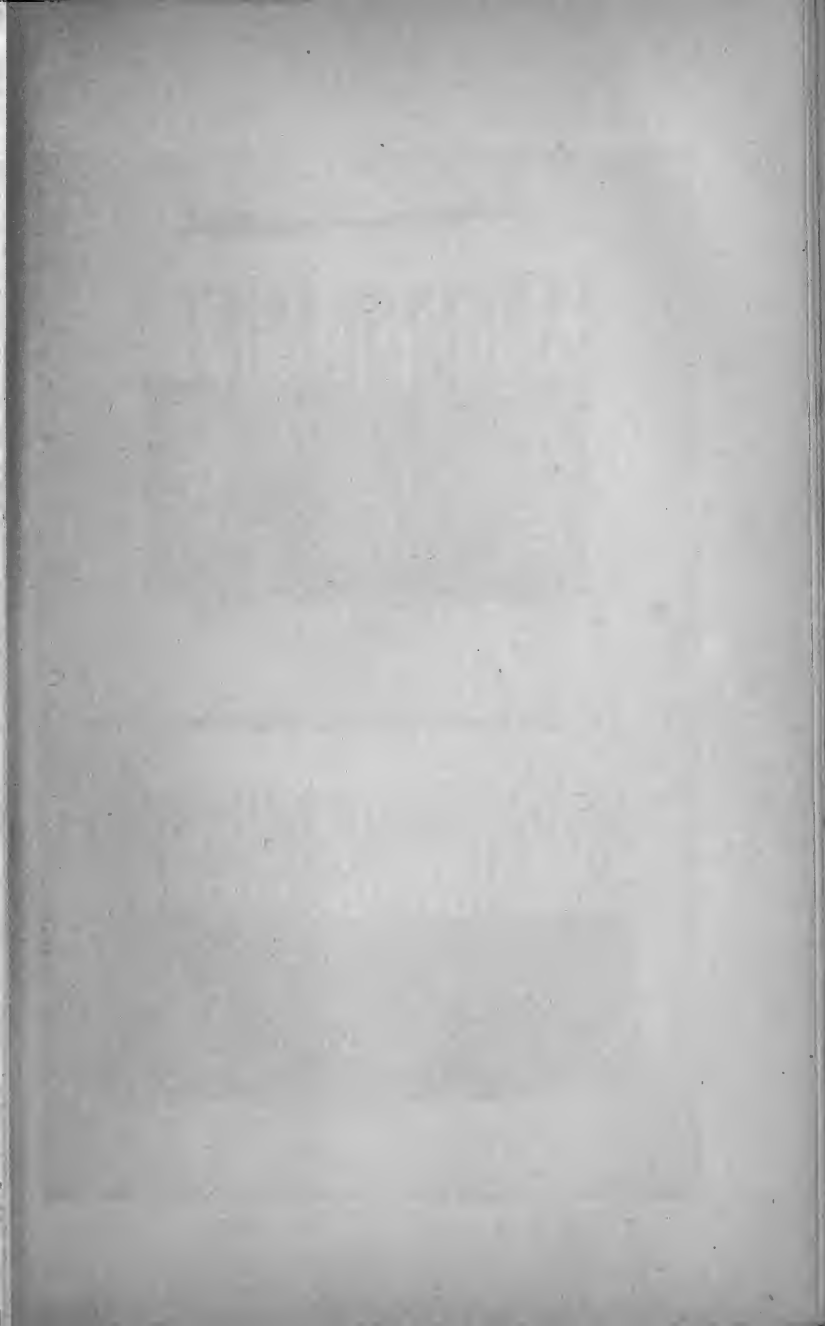


FIG. 2.



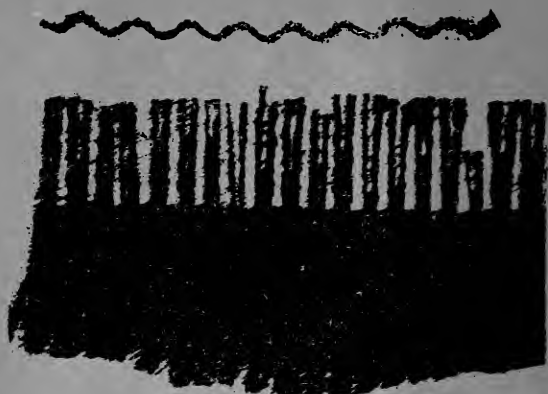


FIG. 3.

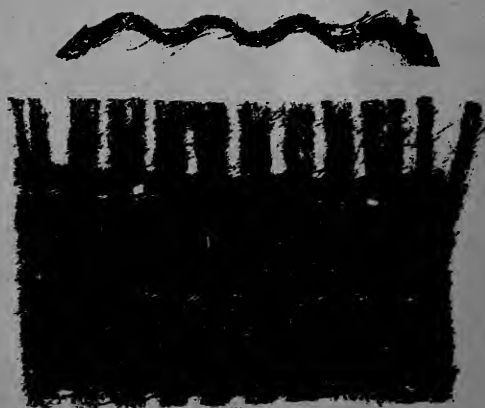


FIG. 4.

It may be stated here, that any reference to the angle of bending, or, the number of threads per inch in a perfect cloth, always refers to the finished fabric, and not as it is in or out of the loom before finishing; for the influences of finishing may have a very material effect upon the ultimate results as will be shown presently.

Let anyone weave a piece of flannel or calico with the warp and weft of the same counts; as the cloth comes from the loom when the warp threads have been stretched, they will appear very straight as compared with the weft; but let the cloth lie for a few days and a change will have taken place. Now wash them and this change will become more marked; the bending in the warp will have increased considerably, and the appearance of the two sets of threads will be the same. This will hold good of twilled as well as of plain cloths, when the order of intersection is such as to bring equal quantities of each to the surface, as in ordinary four or six thread twills or patterns of that character. Hence we have only to determine what angle of curvature is the most suitable to produce a pleasing appearance to enable us to find the number of threads to produce a perfect cloth, when the diameter of the threads are known; this angle shall be determined presently. If the two materials are different in quality or weight, then either the influences of finishing must come in, or the relations of the two to each other,—this must almost invariably be the case—or both must occur. By way of illustration, take first, a cloth made with cotton warp and mohair weft, as shown at Fig. 1, and see what takes place with it. The illustration as shown here is taken from a small piece of cloth by means of photography, and enlarged by a microscope in the process. In the

actual cloth there are about sixty threads per inch. One weft thread has been drawn away from the cloth and appears isolated.

It will be seen at a glance that the weft being the stronger material has caused the warp to bend and become waved, in spite of the tension at which it has been held in the loom, and that is really the normal condition of the fabric, and in such condition it would remain, were not special means adopted in the finishing to alter it. For a cloth of this kind it is necessary that "lustre" should be got up, and the lustrous material is the mohair: but in the condition shown here the lustre or brightness is not of the character required. If the bright material were straight parallel threads, the lustre would be of a metallic character, such as one would see from the surface of a sheet of water, or a piece of metal or silvered glass, which, when the light is thrown upon it, presents one reflection only: but the brightness in this case must be due to many reflections, and this angle of reflection of the parts must be such as to produce harmonious results, therefore the reflecting material must be made to present a series of corrugations or reflecting surfaces to obtain the necessary degree of brilliance. As it stands now it would not do so, and further, the cotton threads intersecting it would interfere with and mar the brilliance of the reflection, consequently in the process of finishing steps are taken to draw the cotton threads into a straight line, and cause the weft to be bent and form such corrugations as will give the best reflecting surface, and at the same time hide the cotton.

A photograph of the same cloth is given at Fig. 2, in the finished state, and one thread of weft has again been isolated so as to show the relative

condition of warp and weft. It will be seen that the conditions are altogether changed: the weft is now waved and the warp is nearly straight, and all the threads are swollen or enlarged.—This may be a little exaggerated in the photograph, as the degree of enlargement is not quite the same as in Fig. 1, still it exists.

The important question now arises, should this angle of curvature have any definite character? or, is there one angle which gives better results in the cloth than another? There can be little doubt that there is one particular angle which gives the best results, and that is when it forms one of sixty degrees with a line drawn vertically through the crest of the waves. In the examination of a large number of cloths of the best recognized types of their class, this has been found to be invariably the case. There is considerable difficulty in making this measurement of the angle, still, as will be seen from the photograph in question, (Fig. 2) when the threads are sufficiently enlarged, the measurement is not only possible but within the range of any one, and it will be more apparent in some of the other illustrations than it is in this one.

Is there any reason why an angle of sixty degrees should be more suitable and satisfactory than any other? There appears to be two at least, and when with these two is mentioned the fact that in cloths of almost every description, each the best of its type, this angle is found to exist, it may be taken as a reasonable ground for working upon, quite apart from the fact that it is a very ready and convenient basis for calculation to determine any number of threads per inch, with any yarn and with any pattern.

In the first place what is termed the angle of vision, or the angle at which the visual rays proceed from the human eye, is said to be one of sixty degrees, and upon this all the laws of perspective are based. Again the angle of the refracting medium most commonly in use, viz:— the flint glass prism, used for the analysis of light is one of sixty degrees, and this is found to give the best results, therefore it seems to follow naturally that if the angle of reflection from corrugated surfaces coincides with this, the results must be more harmonious than would result from any other. In the example given at Fig. 2, this is exactly the case in the cloth, and the result is most satisfactory.

A difficulty at once presents itself here. When dealing with perfectly plain cloths as represented in the illustration, and where one of the sets of threads is drawn out straight, and the bending taking place in the other, there might appear to be comparatively little difficulty, but the difficulty will be increased when bending takes place in an equal degree, or when one yarn is much thicker than the other. Certainly there is more difficulty, but still the rule can be shown to hold good. If bending takes place in both in the same degree, then the angle formed by both should be the same, and the chief difficulty will lie in determining the number of threads per inch to form a perfect cloth because of the necessary decrease in the space between the threads to ensure this angle of sixty degrees in both. If as a starting point it be supposed that the space between the threads should be equal to their diameters, it will not be difficult to ascertain how much this space will be reduced in consequence of one thread bending so much in one direction, and the other a corresponding degree in the other.



Then for a moment turn to the other question or when the two yarns differ; two examples are given at Figs. 3 and 4, in both of which the warp threads are double, and the weft interweaving with them as in a plain cloth, the two warp threads lying side by side and forming one broad flat thread; everything would appear to be altered in such a case as this, but in fact it is not. The crest of the wave formed by the weft assumes a more flat appearance, but the angle it forms in passing from over one set to under another remains the same, or in other words, the space between each pair of threads is suited to the diameters of both weft and warp, so as to form exactly the desired angle. Fig. 3 is a great departure from Fig. 2, but Fig. 4 is a still greater one, and yet the angle is preserved as nearly as possible in both.

There is considerable difficulty at first sight in reconciling this theory with practice, but the most remarkable thing about it is, that practice proves the theory in patterns which would appear to be furthest removed from plain cloths or simple twills, and even in those the apparent contradictions when properly analysed strengthen the case.

Take for instance cloths where the weft is much thicker than the warp, and yet the bending must take place in the weft, all rules would appear to be bad, but when the influence of finishing is taken into account, they prove to be good, as will be demonstrated. But then comes in at this point the question which has already been mentioned, viz: what is termed the balance of cloth which will be affected by the altered relations of warp and weft. No matter what the difference between the two threads may be if the number per inch be regulated to suit the diameter of the threads, and the proper angle of curvature be obtained in the

bending of the threads, whether it be in one set or both, the balance of structure will be maintained, because the increased number of the fine threads will balance the decreased number of the thicker ones and the angle of bending will assist in retaining the balance. It must never be forgotten that the diameters and weight are not in direct ratio, but like circles the sectional areas vary as the squares of their diameters, or the diameters as the square roots of the counts, and as the variation in the number per inch will never be in the same ratio as the alteration in weight, the balance is retained in a degree which would never be anticipated by a casual observer.

Let the student consider for a moment what are the altered relations as regards weight and diameter when he changes the count of his yarn, and also the increased or decreased number per inch, and he will find the change much less than would be suggested by the mere change in counts.

The next step is to consider whether in any but perfectly plain cloths the angle of curvature will be the same, experience shows that it will. If twilled cloths be examined the same result will follow in any pattern or class of twill. If the weft and warp pass under and over a number of threads between the points of intersection the crest or sinus of the wave will be more or less flat as it is in Fig. 4; but at the point where bending takes place the angle is precisely the same in the best cloths. Take, for example, a four thread twill when the weft and warp pass over two and under two threads, or a six thread twill when the weft passes over three and under three, or still further, a satin cloth, when the weft passes over four and under one thread, and the angle of bending in each case is the same.

In many other patterns such as "corkscrew," worsted coatings, and other fancy patterns widely different in character the same angle is found to exist

If this theory be good, and every experiment made with typical cloths, selected from those in regular use, and recognized as amongst the best of their type to be found in the market, then the principle of cloth building may be reduced to an exact science, for if the angle of curvature be known, and the diameter of the threads also, it only remains to place the threads of which a cloth is composed at such distances apart as will produce this angle, making due allowance for the bending of one or both of the sets of threads.

The easiest mode of procedure at first will be to assume that the bending takes place in one set only, as shown in the examples given, and let this be due either to the influences of finishing, or the relative bulk of the threads. It is a matter of no moment which it is due to if it exists in this form, so far as present purposes are concerned, though it would be a matter for consideration in the practical application of the rules.

Then as to this assumption see how the number of threads in a cloth may be determined.

If no bending was taken into account the number of threads per inch would be found by taking into consideration the diameters of the warp threads and the weft threads, and for a plain cloth add the two together and the sum of the two would give the fraction of an inch which they would occupy, and that fraction would of course represent the number per inch, thus:—If the diameter of each thread were  $\frac{1}{118}$  of an inch or  $\frac{1}{118} + \frac{1}{118} = \frac{1}{59}$ , or the space occupied by a thread

of warp and the intersection of the weft would be  $\frac{1}{59}$  of an inch, and as a consequence 59 per inch would be taken as the number which would make a perfect cloth. But if both warp and weft are bent at an equal angle it could not be quite true, because the space between the threads would be slightly altered, and if only one were bent and the other remained straight, it would be still further altered.

If the angle of the bent thread be one of sixty degrees the determination of the distance between one thread and the other is almost as easy to determine as if the space and diameters were equal, because a line drawn vertically through the diameters of the warp and weft, from the centre of one to the centre of the other, would form the altitude of a right angled triangle, having angles of sixty, thirty and ninety degrees respectively. A second line drawn from the centre of the warp thread to the centre of the weft as it intersects the warp would form the base, and a line drawn along the centre of the weft would form the hypotenuse, as shown at Fig. 5. In that



Fig. 5.

drawing both threads are shown as being bent in equal degrees. Then if the altitude of this triangle be known, as it would be from a knowledge of the diameters of the two threads respectively, the base can be easily found; the relations of the three sides of a triangle of this kind are well known. The hypotenuse must be double that of the

altitude, simply because the whole is half of an equilateral triangle, and if the angles are equal the sides must be equal, and being half of the equilateral triangle the longest side must be exactly double that of the shortest. Then if half the diameter of the warp be added to half the diameter of the weft, the altitude is found, and if that be doubled the hypotenuse is found also. Then to find the base subtract from the square of the hypotenuse the square of the altitude and the remainder will be the base squared. This is based upon a well-known rule, and is quite easy of application. Suppose for the sake of argument and to avoid for the moment the use of fractions, that the diameter of each thread be four inches, then half of each would be two inches, and the sum of the two halves four inches as the altitude of the triangle, and  $4 \times 4 = 8$  inches the hypotenuse. Then  $4^2 = 16$ , and  $8^2 = 64$ , and  $64 - 16 = 48$ , and the square root of 48 is

$$\begin{array}{r} 48 \text{ ( } 6\cdot9 \\ 36 \\ \hline 129 \left| \begin{array}{l} 1200 \\ 1161 \\ \hline \end{array} \right. \\ 39 \end{array}$$

so that the base of the triangle would be 6·9 inches.

Instead of working in inches let the student now take the diameter of threads in fractions of an inch and work in the same manner. And if he can work from the yarn in a known cloth all the better, and compare the result of his calculation with the actual cloth.

Attention may now be directed to the determination of the altitude of the triangle, when bending takes place in one direction or the other, or whether

in one or both of the warp and weft threads. The matter will probably be best understood by dealing first with a plain cloth in which both warp and weft are the same both in counts and material, and when of course each would exert the same power of bending upon the other, and consequently each would be bent equally out of their course. This will be better understood by referring to Fig. 5. In that illustration one warp thread is shown as being pressed down for a distance equal to half its diameter, and the next thread is pressed upwards for a similar distance, so that the total bending is equal to a full diameter of the thread, one half in each direction; and as seen, the bending of the weft takes place in exactly the same degree. This is exactly what takes place in plain cloths made in the way suggested, and the altitude of the triangle can be readily found when this is the case, for as shown by the black line, it consists simply of half the diameter of each thread, and on the basis shown when the angle of the hypotenuse of the triangle is one of sixty degrees with the altitude the base can be readily found. Suppose the yarn from which this cloth is made to be 30's worsted, the diameter of which according to my table is  $\frac{1}{117}$ . If the altitude consists of half the warp and half the weft the total will be equal to the whole diameter of one thread, or  $\frac{1}{117}$ .

Now see how this works out:  $\frac{1}{117}$  is the altitude of the triangle, and double that or  $\frac{2}{117}$  is the hypotenuse, and if each of those fractions be squared they will give  $\frac{1}{13689}$  and  $\frac{4}{13689}$  respectively, then subtract the square root of the altitude from the square root of the hypotenuse and we have  $\frac{4}{13689} - \frac{1}{13689} = \frac{3}{13689} = \frac{1}{4563}$  as the length of the base squared, and extract the square root of  $\frac{1}{4563} = \frac{1}{675}$  as the distance from the vertical line drawn

through the centre of one thread to a corresponding one drawn through the centre of another, therefore this represents the exact distance from centre to centre of the threads, and consequently the number per inch which the cloth should contain.

The student will now see the force of the remark made before with reference to the spaces between the threads being equal to the diameters of the threads themselves in a typical plain cloth. This basis has been taken hitherto although it was well known that it never gave exactly the results desired, and when the bending of the threads is taken into account it is quite easy to understand why this should be the case; because whatever degree of bending occurs the space between the threads must be reduced, and the only question is as to the requisite amount of space required to give an angle which ensures the best results; and whether there is reason or not for one of sixty degrees, it certainly is a convenient one, and without doubt gives good results in the cloth.

It is quite immaterial whether the calculation be worked by means of fractions or decimals, some will prefer to work by one method and some by the other. I will give the working in decimals, and then try to abbreviate the whole operation for convenience. There is no doubt that many good rules are cast aside because they are cumbrous, and yet they are quite capable of being reduced to simplicity. See what can be done in this case.

First reduce the altitude to a decimal and it will be  $\frac{1}{117} = .008547$  as the altitude and  $.008547 \times 2 = .017094$  for the hypotenuse, then  $.008547 = .000073250209$ , and  $.017094^2 = .000292204836$ , then subtract the square of the altitude from the

square of the hypotenuse thus  $\cdot 000292204836 - \cdot 000073250209 = \cdot 000218954627$  as the square of the base, and the square root of that will be  $\cdot 014797$ , which divided into units gives  $67\cdot 5$ .

This method is very cumbrous by reason of the large number of figures which must be employed, and it is a matter of necessity to work to a large number of places of decimals otherwise the accuracy of the results would be very much impaired. Then see how this may be abbreviated.

It has been shown that the hypotenuse of this triangle is just double the length of the altitude by reason of its being half an equilateral triangle, and that the base bears a relation to the two sides dependent upon their squares, let  $a$  represent the altitude,  $b$  the base, and  $c$  the hypotenuse, then  $c^2 - a^2 = b^2$  and we say that  $c$  is double the length of  $a$ , or  $2a = c$ , therefore it follows that  $\frac{c}{2} = a$  and if  $c^2 = b^2 + a^2$  it follows that  $b^2 = c^2 - a^2$

$$\therefore b^2 = c^2 - \left(\frac{c}{2}\right)^2$$

$$\therefore b^2 = \frac{c^2}{1} - \frac{c^2}{4} \text{ and } \frac{c^2}{1} - \frac{c^2}{4} = \frac{4c^2 - c^2}{4} \text{ or } \frac{3c^2}{4} \text{ therefore}$$

$b^2 = \frac{3c^2}{4}$  and to extract the square root of each side of the triangle we should have  $b = \frac{\sqrt{3}c}{2}$ , and  $\frac{c}{2} = a$ , therefore  $b = \sqrt{3}a$ , consequently instead of squaring  $a$  and  $c$  respectively, and extracting the square root of their difference, multiply the altitude of the triangle by the  $\sqrt{3}$  which is  $1\cdot 732$ , and we obtain at once the value of  $b$ , so that  $1\cdot 732$ , may be used as a standard multiplier, and the number of threads per inch is found at once.

To work with this standard it is much easier to deal with fractions than decimals, because the fraction of an inch representing the diameter of the thread is reduced for convenience to the lowest term with the numerator as one; and as in the case in hand it is  $\frac{1}{117}$ , then  $\frac{1}{117} \times 1\cdot 732 = 67\cdot 5$  or in



other words take the diameter given at pages 138 to 143 or those dealt with in these articles, and found by extracting the square root of the yards per lb., and divide by 1.732, and the answer will be the number of threads per inch in the cloth, thus  $\frac{1.17}{1.732} = 67.5$ . Suppose the counts were 40's worsted the diameter of which is  $\frac{1}{35}$ , thus  $\frac{1.35}{1.732} = 77.9$  or nearly 78 per inch.

Now to still further simplify the matter for those not very familiar with figures, take the diameter as it stands in the table or as found by the other method, add three ciphers to compensate for the three decimal points in the standard multiplier, which now becomes a standard divisor, and divide by 1732, thus  $\frac{135000}{1732} = 77.9$

The question will now arise whether two yarns of varying diameters may be used for the same cloth, by the application of the same rule. There will be two considerations involved in this, first whether the finishing will so influence the bending powers that each thread will be bent out of its course a distance equal to half its diameter, and second, whether the threads will be allowed to exert their natural influence over each other, and each be bent according to the strength of the other and its own resisting power. Those coming under the first head may be dealt with at once, and they form a larger number of fabrics than might be supposed, and the second will be dealt with presently. Then assuming that each thread is bent one half its diameter out of its course, the altitude of the triangle will always be the sum of half the diameter of each, no matter what they may be, therefore the operation will be the simple addition of the two diameters and dividing by two, add the three ciphers as suggested and divide by 1732, and the answer will be the number of ends

per inch required. Take for example a cloth made with 30's worsted warp, and 60's worsted weft. The diameter of 30's is  $\frac{1}{117}$ , and of 60's  $\frac{1}{165}$ , then  $\frac{1}{117} + \frac{1}{165} = \frac{282}{19305} = \frac{1}{68} \div 2 = \frac{1}{136}$ , and  $\frac{136000}{1732} = 78$  the number of ends per inch required.

Now suppose a cotton cloth is to be made under the same conditions. Let the warp be 40's, and the weft 60's. The diameter of 40's cotton is  $\frac{1}{165}$ , and 60's  $\frac{1}{202}$ , and  $\frac{1}{165} + \frac{1}{202} = \frac{367}{32330} = \frac{1}{88}$  and  $\frac{1}{88} \div 2 = \frac{1}{176}$ , and  $\frac{176000}{1732} = 101$  the number of ends per inch required.

The same rule will apply to any material, or to any combination of materials, for if it is true of one it must be true of all; it is only a question of finding the diameters of the several yarns to be used, and proceeding in the same manner throughout. Suppose the warp to be 30's cotton, and the weft 32's worsted, then the diameter of 30's cotton is  $\frac{1}{142}$ , and 32's worsted  $\frac{1}{120}$ , and  $\frac{1}{142} + \frac{1}{120} = \frac{262}{17040} = \frac{1}{65}$  and  $\frac{1}{65} \div 2 = \frac{1}{130}$ , and  $\frac{130000}{1732} = 75$  the number per inch required.

Another question arises now in reference to this. In a great many cases the influence of finishing causes one of the threads to be drawn into a straight line, and the bending to take place only in the other, and this is notoriously the case in goods made with cotton warp and worsted weft, as it is in many others, the chief object being to produce a series of corrugations in the brighter material, and so obtain all the lustre possible. When this takes place a change comes over the calculation, but the principle is in no degree affected. If a section be made of a cloth of this kind the warp threads would appear in the same straight line and not one pressed upwards and the other down as is the case in Fig. 5 already referred to. This will be at once apparent on reference to Figs. 2, 3,

and 4. In such a case as that the weft passes clear above the line of warp threads in going over one thread and equally clear below it in going under the next one, consequently the altitude of the triangle will not be half the diameter of each, but the full diameter of both warp and weft, so that the angle is obtained on each side of a line drawn through the centre of all the warp threads. This, as will be seen at once, only effects the calculation, in so far as finding the altitude of the triangle is concerned by taking the full thickness of both the warp and the weft into account. Take the example last given and assume that it has been finished so as to draw the warp threads straight. The diameter of the warp is  $\frac{1}{142}$ , add to this the diameter of the weft  $\frac{1}{120}$ , and it will give  $\frac{1}{142} + \frac{1}{120} = \frac{262}{17040} = \frac{1}{65}$ , and  $\frac{65000}{1732} \approx 37.4$  ends per inch. There is a wide difference between those two, but when the fact is taken into account that the angle formed by the weft is the same, and that the warp threads have not been bent, the spaces between the threads must necessarily be larger.

Attention must now be called to a point which was referred to previously. The diameters dealt with here are taken from the table of measurements made from yarns in the grey state, therefore their diameters would be altered in the finishing, and experience shows that about ten per cent. may be added to what is found, or added to the diameter of the threads, to obtain perfection, and when this is done the result comes as nearly as possible to the best cloths made.

The principle is so far laid down in the most unmistakable manner for plain cloths, and anyone may apply it to known cloths of good make and see how far it is true, and having done that the subject may well be considered further.

The next subject for consideration is the relative bending powers of the warp and weft respectively, and the influence they will exercise in each direction; the object being to ascertain the exact altitude of the triangle, though in a large proportion of cases the influence of finishing would not only neutralise the natural powers, but actually reverse the conditions, as is evidenced in many lustre goods when the warp is much thinner than the weft, yet all the bending practically takes place in the weft, and what little does take place in the warp might almost be ignored in the calculation. It may be said further also, that the great majority of cloths will come under one of the two heads dealt with for the calculation, viz:— when both threads are bent equally, and the altitude of the triangle is equal to the sum of half the diameter of each, and when the bending takes place in one thread only, the altitude would be equal to the full diameter of the straight thread, and the full diameter of the bent one, and upon one of these two bases almost any calculation may be worked, without taking the actual powers of the two yarns into account.

The bending powers of threads like all other bodies will vary in the ratio of the cubes of their diameters, therefore their actual influence upon each other can be readily ascertained, and the altitude of the triangle found at once, because it would simply mean that the displacement of each from the straight line would have to be considered in determining how much would have to be taken into account as forming the altitude of the triangle. Suppose for example that when the diameters of the two threads are cubed, the bending powers are as two to one, then the displacement of one would occur equal to two-thirds of a diameter, and of the

other equal to one-third: the least displacement of course taking place in the thick thread, and the greatest in the thin one, consequently the altitude may be found at once, and from that, the ends per inch. When dealing with other than plain cloths the mode of working is slightly altered, though the principle remains the same. Whenever the weft passes over more than one thread between the points of intersection, then the space occupied by the whole pattern must be found, and from that the number of threads per inch. Take for example



the pattern given at Fig. 5, where the weft passes over two and under one thread: in this there are two intersections on the first pick, one between the second and third

threads, and one between the third and the repetition, and so on. Consequently each of those intersections would form a triangle just as in a plain cloth, but the space occupied by the thread where no intersection takes place would be represented by its own diameter, and the space for the whole pattern would be equal to the base of two triangles and the diameter of one thread.

Now suppose the warp to be 2/40's cotton, and the weft 60's worsted. The diameters of 2/40's cotton would be  $\frac{1}{118}$  that of 60's worsted  $\frac{1}{165}$ . There would be some bending power exercised upon each of those, but for the moment let it be assumed that bending takes place in the weft only, as that would practically be the case: then the altitude of the triangle would be the diameter of the warp plus the diameter of the weft. Thus,  $\frac{1}{118} + \frac{1}{165} = \frac{283}{22470} = \frac{1}{80}$  nearly.  $\frac{1}{80} \times 1.732 = \frac{1}{46}$  as the base of the triangle, then two such triangles and the diameter of a thread of warp will be  $\frac{1}{46} + \frac{1}{46} + \frac{1}{118} = \frac{141}{2714} = 18.7$  patterns per inch, and  $18.7 \times 3 = 56.1$  ends per inch for the cloth.

Now take a four thread twill, the weft passing over and under two alternately, as in Fig. 6, and let the warp and weft be equal, so that bending in that case would take place in both directions in an equal degree. Let the counts be  $2/48$ 's

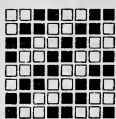


Fig. 6. worsted or equal to  $24$ 's single, the diameter of which is  $\frac{1}{104}$ , then  $\frac{1}{104} \times 1.732$ , or  $104000 \div 1732 = 60.6$ , then two such triangles would be equal to  $30.3$ . The two diameters where no intersections take place will be  $\frac{1}{104} \times 2 = \frac{1}{52}$ , and  $\frac{1}{52} + \frac{1}{30.3} = \frac{82.3}{1575.6} = \frac{1}{19}$ , 19 patterns per inch, and as there are four threads in the pattern,  $19 \times 4 = 76$ , the number of threads per inch required in the cloth.

Suppose the cloth just dealt with had been cotton, woollen or linen, the method of working would have been precisely the same, only using the diameter of the yarn in the system dealt with instead of that of worsted, and that practically means that the number of threads found would be the same for any material having the same diameter, but from the system of counting the number by which the yarn is known would be different. By way of further illustration take a cotton cloth, and suppose the warp and weft to be equal again to  $2/48$ 's or single  $24$ 's. In that case the diameter would be  $\frac{1}{128}$ . A casual observer would say that  $24$ 's worsted being equal to  $16$ 's cotton, the number of threads in cotton, would be reduced proportionately, but what has been said of the relative diameters of yarns should make this quite clear, and show that this could not be so. For the purpose of further demonstration a cloth may be worked out for  $24$ 's and  $16$ 's cotton, so as to show clearly the comparison.

In this case the bending being again equal in

both directions the altitude of the triangle would be  $\frac{1}{1\frac{1}{2}8}$ , and the base  $\frac{1}{1\frac{1}{2}8} \times 1.732 = \frac{1}{73.3}$  and the pattern will occupy the space of two triangles and the diameters of two threads: then two triangles will be  $\frac{1}{73.3} \times 2 = \frac{1}{36.6}$ , and two diameters  $\frac{1}{1\frac{1}{2}8} \times 2 = \frac{1}{64}$ , and  $\frac{1}{36.6} + \frac{1}{64} = \frac{100.6}{23424} = \frac{1}{23}$  nearly, or there would be 23 patterns per inch, and  $23 \times 4 = 92$  ends per inch for the cloth.

Now to take the 16's yarn, the diameter of which is  $\frac{1}{104}$ , the same as the 24's worsted, so that as the diameters are the same, the number of threads per inch would be the same, although the yarn is spoken of by a different number.

Next as to the relations of the counts, diameters and the number of threads per inch. It is clear that the number of threads cannot vary in the ratio of their counts, but for the same pattern they vary in the ratio of their diameters, and this is an important factor in changing from one weight to another, or in changing from one count to another, for if a perfect cloth be built in one count, and it is desired to build another equally perfect from another given count, the working out is simply one of proportion. See how clearly this stands. In the 24's worsted (equal to 16's cotton), the number of threads found was 76, ignoring fractions, and in the 24's cotton the number found is 92. If the question had been worked simply as a proportion based on the counts, it would have been as 16:24 :: 76:114. Which to any practical mind would be manifestly absurd; but when dealt with on the base of the diameter it stands as 104:128 :: 76:93,—the difference between 92 and 93 being due solely to the small fractions which occur in the working—thus showing that on this basis a cloth may be changed from any one count to any other

at will, and retain the perfection of structure. The question of changing weight from one fixed standard to another has been dealt with in this book already.

Now go one step further, and take a pattern such as is given at Fig. 7. Where the weft passes over three and under three threads, and again assumes that warp and weft are equal, and consequently bending taking place equally in each. In this there would be two intersections for six threads, therefore the space occupied by one

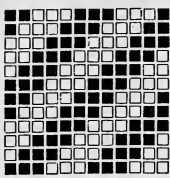


Fig. 7.

pattern would be equal to the bases of two triangles, and the diameters of four threads. Then suppose the warp and weft to be  $2/30$ 's or equal to  $15$ 's worsted, the diameter of which is  $\frac{1}{8.3}$  then the base of the triangle would be  $\frac{1}{8.3} \times 1.732 = \frac{1}{4.8}$  nearly, and  $\frac{1}{4.8} \times 2 = \frac{1}{2.4}$ , then four threads will occupy a space of  $\frac{1}{8.3} \times 4 = \frac{1}{2.1}$  nearly, and  $\frac{1}{2.4} + \frac{1}{2.1} = \frac{4.5}{5.04}$ , or  $11\frac{1}{5}$  patterns per inch, and  $11\frac{1}{5} \times 6 = 67.2$  ends per inch. Of course there is again a slight inaccuracy here owing to small fractions being ignored, but the whole would amount only to a fraction of an end, and would therefore be sufficiently correct for all practical purposes. It may be said that although this rule works out for such simple twills as those already dealt with it cannot work out for patterns of a more fancy character, but it must work out with equal truth for all. Take for instance such a

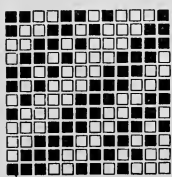


Fig. 8.

pattern as Fig. 8, which might be called a first step towards a fancy twill: there is nothing more to do than to find the number of intersections, and the number of threads where no intersection takes place,— and the two added together must always be equal to the number of

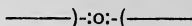


threads in the pattern,—and by adding together the bases of the triangles, and the diameters of the threads as shown the number of threads per inch must be found exactly as for any simple twill.

Now comes the question of the warp and weft being unequal, or of patterns which must have more threads in one direction than another. The general principles of dealing with this class of cloth have been already fairly well established, and it only need be said now that when the warp and weft are so widely different that bending is likely to take place in one, then the altitude of the triangle must be as already laid down: the full diameter of the straight thread, and the full diameter of the bent one, and if both are bent then the degree of displacement of each must be considered, and the altitude of the triangle found, and the rest of the operation will be just the same as already given.

Suppose that the warp is extremely fine and the weft thick, bending would take place in the warp altogether, and the weft would go in as a perfectly straight cylinder. In that case the rules would determine the number of weft threads per inch, and the warp threads would be placed as closely together as possible, so that the number per inch, would be determined by the actual diameters, and in some cases even subjected to some slight degree of compression. In the same manner if the warp be thick and the weft thin, the weft will be bent round the warp, and the rules will apply to finding the number of warp threads per inch, the weft being determined by the diameters of the threads and laid as closely together as possible. This rule will hold good in the case of either plain or fancy cloths, such as some of those referred to in the early part of these lessons.

## APPENDIX B.



The basis of the various Counts systems.

WORSTED—The hank of 560 yards, the number of hanks per lb. indicating the counts.

COTTON—The hank of 840 yards, the number of hanks per lb. indicating the counts.

SPUN SILK—As cotton, except that in two-fold yarns the hanks per lb. for a given count are the same as single, whereas in cotton there are half the number, as  $2/30$ 's cotton contains 15 hanks per lb., in silk, written  $30/2$ , there are thirty.

RAW SILK—(Denier Scale)—The weight of the denier is 0.823 grains, the length of the hank 520 yards

RAW SILK—(Dram Scale)—The weight in drams avoirdupois of 1000 yards.

RAW SILK—(Ounce Scale)—The number of hanks of 1000 yards each weighing 1 oz.

LINEN—The "lea" of 300 yards, the number of leas weighing 1 lb. indicating the counts.

WOOLLEN—(Yorkshire Skein)—The number of yards weighing 1 dram, or the skeins of 1536 yards weighing 6 lbs.

WOOLLEN—(West of England)—The number of times 20 yards will weigh 1 oz., or the hanks of 320 yards per lb.

WOOLLEN—(Cumberland Bunch Count)—The weight in ounces of a bunch of 3360 yards.

WOOLLEN—(Dewsbury)—Yards per oz.

WOOLLEN—(Sowerby Bridge)—The weight in drams of 80 yds.

WOOLLEN—(Galashiels)—The cuts of 300 yards each in 24 oz. or 384 drams.

WOOLLEN—(Hawick)—The cuts of 300 yards in 26 oz. or 416 drams.

The SPYNDLE consists of 14,400 yards.

AMERICAN SYSTEMS—

The "Run" is based upon 100 yards per oz.

The "Grain" system, the weight in grain of 20 yards.

The "Cut"—The cuts of 240 yards in 1 lb.

The "Hole"—Upon 60 yards.

THE FOLLOWING ARE THE SEVERAL CONTINENTAL SYSTEMS  
OF DETERMINING THE VALUE OF ONE DENIER  
OF RAW SILK.

SYSTEM.	Revolutions of Reel.	Circumference of Reel in Centimetres.	Length of Thread.	Weight of 1 Denier in Grammes.
International Denier	400	125 c/m.	500 m.	0.05 gr.
New	„	112 $\frac{1}{2}$ „	450 „	0.05 „
Milan	„	119 „	476 „	0.0511 „
Turin	„	119 „	476 „	0.05336 „
Lyons (Old)	„	119 „	476 „	0.05311 „
„ (New)	„	125 „	500 „	0.05311 „

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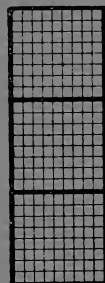


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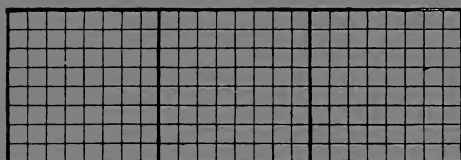
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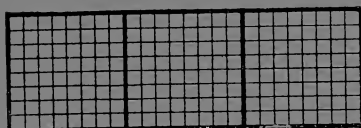
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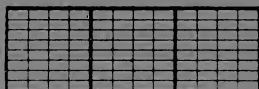


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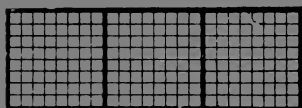


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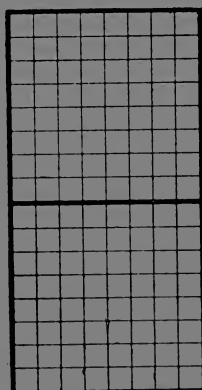
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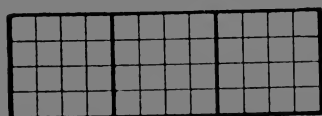
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